The HOW AND WHY Wonder Book of

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PLANETS AND INTERPLANETARY TRAVEL

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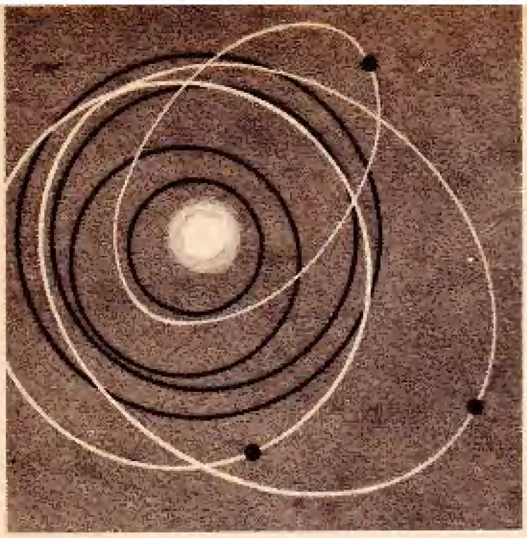

Introduction

Are you on the waiting list for a rocket trip to the moon or one of the planets? You may not have long to wait, for it has already been shown that men can be sent to outer space and returned safely to earth. It is a goal of scientists to extend space explorations beyond the moon with and without astronauts.

Successes in space exploration are based on the proper application of scientific facts and principles relating to the laws of motion, the mechanics of flight, outer atmosphere, the planets and our solar system, and rocket fuels. *The How and Why Wonder Book of Planets and Interplanetary Travel* deals with many such facts and principles in an easy-to-understand way. Future flights into space will build on this knowledge and thus add new knowledge.

This intriguing book also explores the problems faced by scientists as they try to accomplish man's age-old dream of probing outer space. Can we use nuclear power for rocket fuel? How can we navigate a spaceship? Why are spaceships needed? Can man live on the moon? Answers to these and a multitude of other questions bring the reader up-to-date on space information. At the same time, further questions are propounded—ones for which scientists still seek answers. Thus is curiosity stimulated, and the work of science goes on.

If you are a hopeful candidate for a rocket trip, or merely an armchair observer of such events, you will find *The How and Why Wonder Book of Planets and Interplanetary Travel* a significant reading experience.

Paul E. Blackwood

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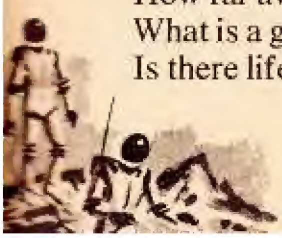
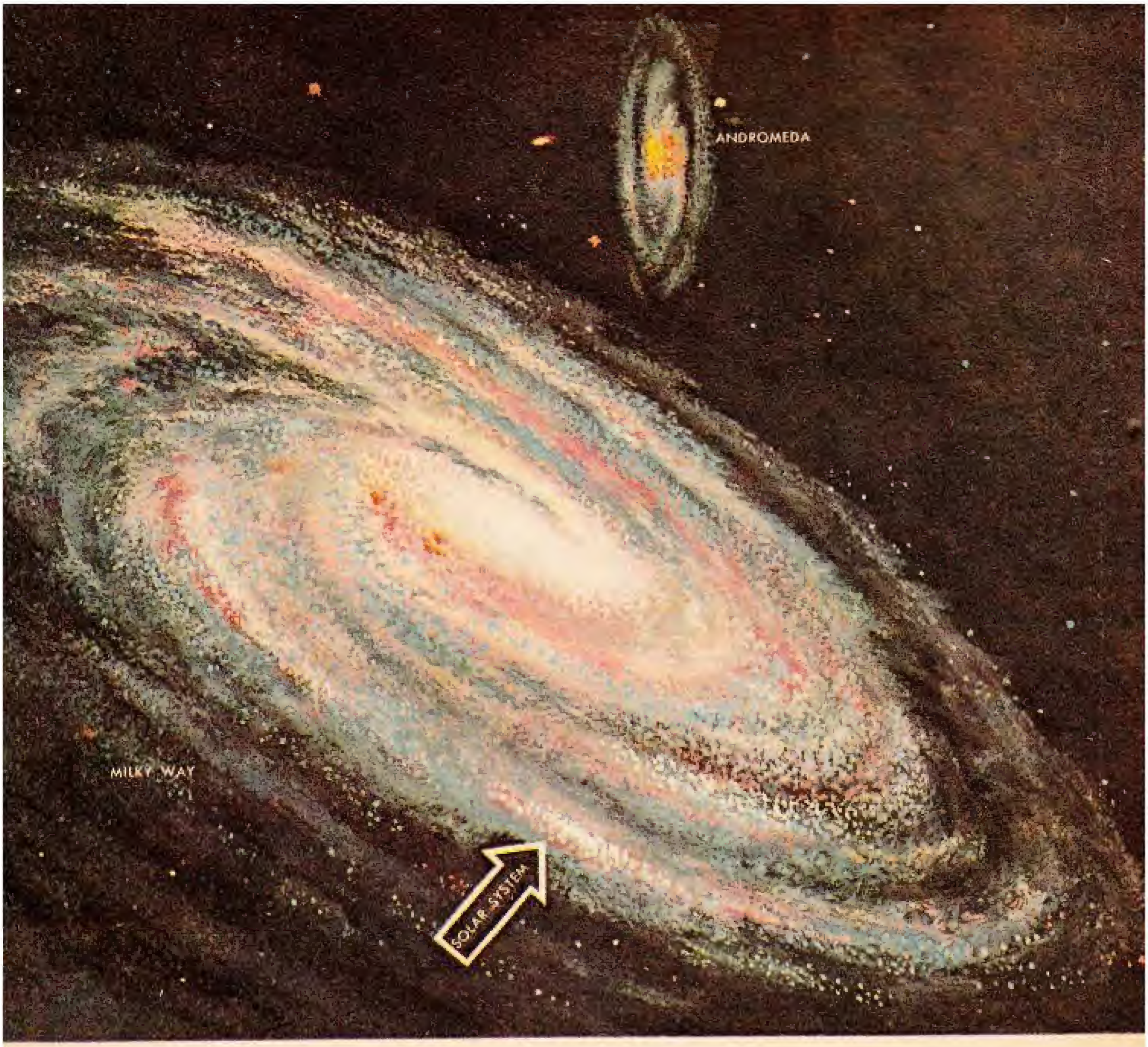
Contents





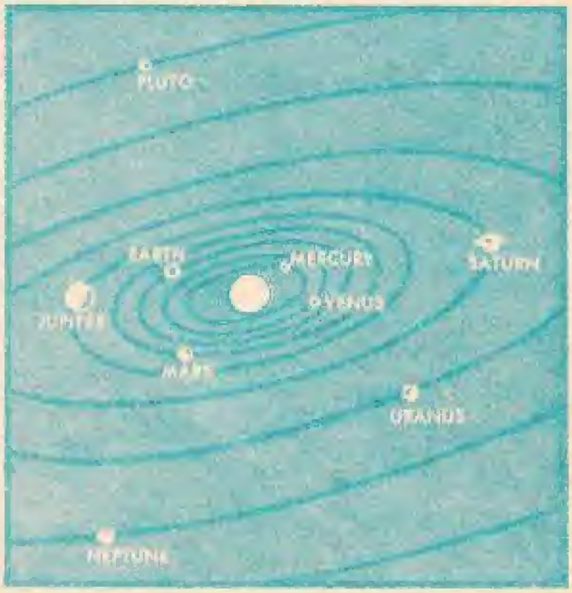
Shaping the Space-Age Dream

Why should we explore space?

Man has always looked for new lands, new mountains, new worlds to conquer. For some, there was a practical reason, such as searching for gold, or for an even more precious commodity—freedom. For others, there was the adventure and romance of being the first man to fly across the ocean or the first man to explore an unknown cave.

Ever since early history, man has been curious. First, he explored his cave, then the land, next the sea and eventually the

The universe in which we live is so vast that we still have not discovered exactly how big it really is. Throughout the universe there are millions of galaxies similar to the ones shown here. Our earth and sun—in fact, our entire solar system—is but a minute part of our galaxy. There are more than 100,000 million stars in our galaxy and many astronomers believe that there are other planets, in addition to those in our solar system, that are revolving around these distant suns.



air. Today, man stands at a new frontier—space and space travel.

What is outer space?

There is no definite boundary between the earth's atmosphere and space. If you were to go up from the ground in a rocket, you would find that the air gets thinner and thinner as you get further away from the earth until there is none at all. This is what we call *outer space.*

Although scientists have not agreed upon where outer space begins, there are many who feel that once we are about 600 miles above the earth, we are at the bottom fringe of outer space. If this is the bottom, where is the top?

The top or farthest reaches of outer space are millions and millions of miles away. No matter how far away from the earth we go, we would still be in outer space. In effect, we would be travelling through the universe (u-ni-verse). The

universe is the biggest thing we can picture. Everything we know of is in the universe—our earth, the sun, the very distant stars. Therefore, no matter how far out we go from earth, either by exploring with our telescopes or flying in a spaceship, we would always be in the universe and never reach the end of outer space.

When did man first dream of space travel?

The dream of leaving the earth and reaching another world can be traced back in history to the second century A.D. At that time a Greek, Lucian of Samos, wrote a fantasy about a man who was carried to the moon by a waterspout during a storm. In his second story about space, Lucian's hero flew to the moon with a pair of wings he had made himself.

The moon was the obvious destination for such fantasies because it is so large and has clearly visible markings, which could be thought of as land and sea areas. But for the next 1,400 years, the dream of reaching the moon was abandoned. During this period men believed that the earth was the only world that had ever been created, and that the sun, moon and stars were there to give light and comfort to the earth.

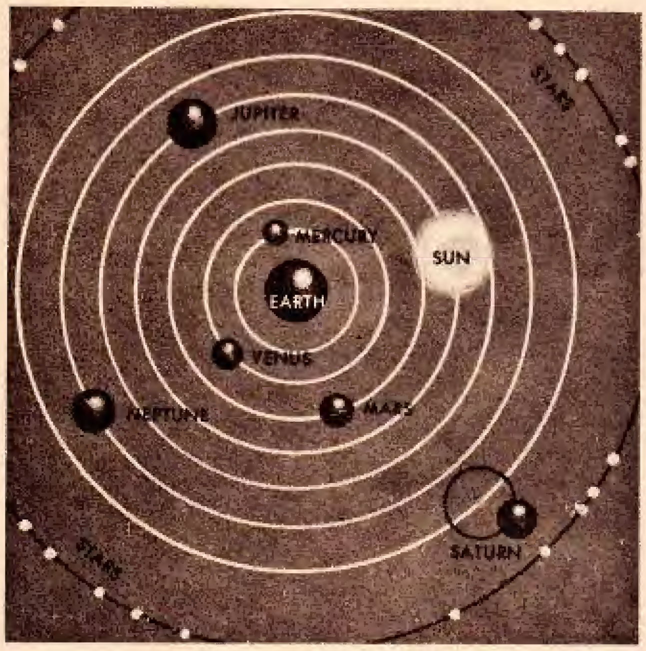
It was not until some 300 years ago, when the famous Italian astronomer Galileo looked through his telescope and told about the other worlds he saw, that men realized there were other worlds in addition to our earth. Again, they began to dream of reaching these worlds.

In 1634, there appeared a story about a journey to the moon by Johannes Kepler, the German astronomer who discovered how the planets moved about the sun. Although Kepler was a scientist, he transported his hero to the moon by "magic moon people" who could fly through space. Kepler did include a detailed description of the surface of the moon, which he had seen through his telescope.

After Kepler's book, there were many others about space travel and voyages to the moon. They were mostly fantasies, but some contained attempts at scientific reasoning. The first serious discussion of space travel was written in 1640 by Bishop Wilkins of England. It contained a description of physical conditions on the moon and discussed ways in which man could possibly live on the moon. The first man who wrote about a rocket as a spaceship was the noted Frenchman, Cyrano de Bergerac. In his *Voyage to the Moon* and *History of the Republic of the Sun*, written in 1649 and 1652, he had his space travellers flying to the moon and the sun inside a rocket.

When these books were written about 300 years ago, no one seriously thought that it would be possible to fly through space. It was not until Jules Verne, the French novelist, wrote his story *From the Earth to the Moon* in 1865 that any attempt was made to apply known scientific principles to the space vehicle. By

In the second century A.D., the Greek astronomer Ptolemy believed the sun and planets revolved around the earth.



the time that H. G. Wells, the English author, wrote *The First Men on the Moon* in 1901, man was already at the beginning of a new era in the development of air travel and the conquest of space.

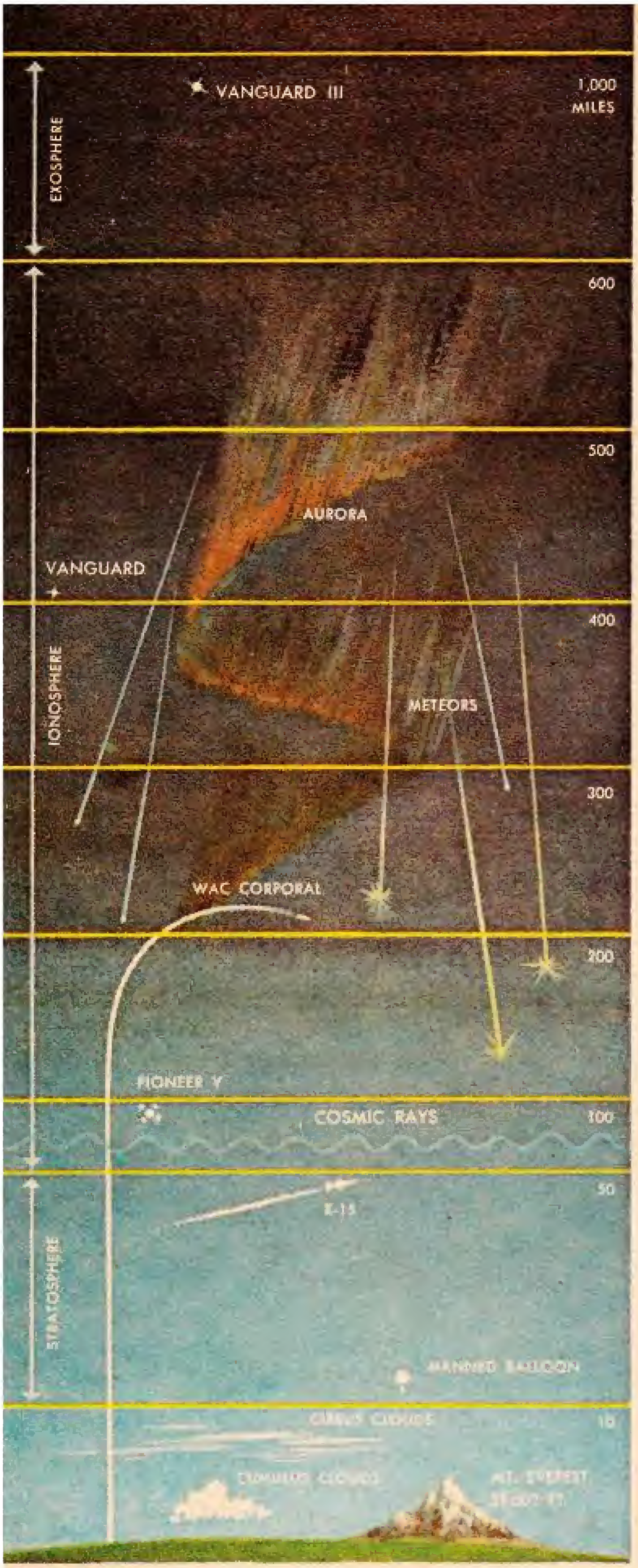
Galileo built his first telescope in Italy in 1610.

The Earth and Its Atmosphere

What is the atmosphere?

The *atmosphere* (AT-mos-phere) is a mixture of gases that surrounds the earth. It is composed of oxygen, nitrogen, carbon dioxide and other gases. Scientists have divided the atmosphere into four layers or levels. Closest to the earth, up to a height of about 10 miles, is the *troposphere* (TROP-o-sphere). This layer contains nine-tenths of all the air surrounding the earth. It is in this layer that our clouds are formed and our weather is made.

The second layer, the *stratosphere* (STRAT-o-sphere), which starts 10 miles up and extends to about 50 miles, contains much less air than the troposphere. Here it is very difficult to breathe, since there is very little oxygen. Above this layer is the ionosphere (i-ON-o-sphere), which extends to 600 miles above the earth. In this layer there is very little air, and it would be impossible to live in the



The air between earth and outer space is the atmosphere.

ionosphere for a few minutes without extra oxygen needed for breathing. Furthermore, the sky around you at this level appears black even when the sun is shining.

Finally, at 600 miles up and beyond to the far reaches of the universe is the exosphere (EX-o-sphere). This layer contains practically no gases or air and is very, very dark. The exosphere extends out beyond the moon, sun and distant stars.

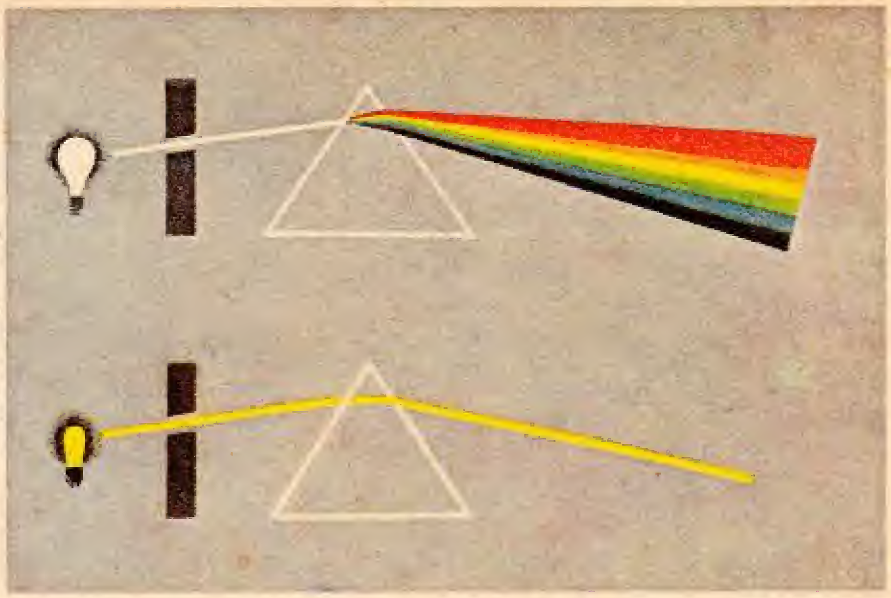
How have we probed the near-reaches of space?

Man has been probing space ever since he first turned his eyes skyward to observe the sun, moon and stars. It was not until 1610, however, when Galileo developed his telescope, that man really began to explore beyond the earth. While the telescope provided much information about the heavens, it is only recently that we have obtained detailed information about the space surrounding the earth.

We gathered this information in many ways. First, astronomers used the spectroscope (SPEC-tro-scope) with their telescopes to determine the composition of the stars. The spectroscope is an instrument which uses a prism to separate light rays into their colours. Every element in nature emits a special combination of colours when very hot. The combination for each element is as distinctive as a fingerprint. Each star, like our sun, is very hot and emits rays of light. Therefore, by analyzing these colour combinations, it was possible to determine the substances which exist in the stars.

As well as emitting or reflecting light, some stars and planets give out radio and other waves. Scientists have developed radio telescopes to collect radio waves in the same way that ordinary optical telescopes collect light. Earthbound astronomers can only use waves that can

When light from a source such as the sun or a light bulb passes through a prism, it is refracted (bent) and broken up into an array of colours like a rainbow. When the light given off by a very hot chemical element is passed through a prism, it is broken up into a unique combination of colours. This is called its spectrum, and identifies the particular element. Astronomers can tell what elements exist in the stars by studying their spectra.



pass through our atmosphere, but now telescopes of all types can be launched into space to detect, for example, X-rays. Some scientists send out radio waves to the moon and the planets. These bounce off a planet, like a ball bounces off a wall, and the return signal carries information about the planet back to earth.

Since man has been able to launch rockets into space, scientists have been devising experiments that can be carried in rockets, satellites or space probes. These experiments are designed to study our atmosphere, the space around it and our solar system. The satellites that orbit the earth look both outwards to space and inwards to the earth, while space probes leave earth and travel to the moon and the other planets.

There are several advantages in having a man in space to operate experiments, as they did in the Skylab orbiting space station. Men can repair equipment that goes wrong, and can adjust experiments where necessary to make them more flexible.

What are cosmic rays?

Our sun is a massive, intensely hot body that is composed mainly of two gases—helium and hydrogen. Inside the sun these gases are pressed together under great pressure. The pressure is so great that the atoms, or basic chemical elements in the helium and hydrogen gases, are crushed together.

This crushing together of the atoms results in a tremendous release of energy, which is given off as heat, light and other rays. Cosmic rays are one of these other rays and they travel at a very, very high speed. These rays spread out from the sun and the stars in all directions and some reach the earth.

What is the danger of cosmic rays?

Exposure to a large amount of cosmic rays would result in severe burns or even death. These rays destroy body tissue and the blood cells in our bodies. Fortunately, only a small portion of these rays reach us here on earth.

ABSORPTION SPECTRUM OF THE SUN

Measurements by satellites and space probes have shown that cosmic rays are trapped in a doughnut shaped region surrounding the earth. This Van Allen region, named after the scientist who discovered it, starts about 370 miles above the earth's surface and reaches out to about 40,000 miles. Below it, cosmic radiation is very weak, and above it, the radiation is not strong enough to harm spacemen on short journeys, except during major solar flares. However, these flares do not happen very often—only about once a year on average.

So short journeys, such as those to the moon which take about a week, are safe enough. Of course, the spacecraft has to cross the Van Allen region, but this takes a very short time and the danger is small. Spacemen orbiting the earth in space stations stay below the bottom limit of the Van Allen region.

Are other rays also dangerous?

Two other rays given off by the sun have created problems for the space traveller. The invisible gamma rays and the dangerous ultraviolet rays are stopped by the atmosphere above the earth. Like the cosmic rays, only a small portion of these ever reach the earth.

The gamma rays can be stopped in space by the metal surface of a spaceship. The ultraviolet rays, which cause severe burns, can be stopped by a special type of glass. Thus, it is possible for the spaceman to be protected from these rays. The shielding necessary to protect him against cosmic rays is much too heavy to be practical in a spacecraft, but shielding is not necessary on short trips. When men fly to the planets, taking perhaps a year for the journey, some protection could be provided by arranging the equipment in the spacecraft to form a shield.

What is space debris?

Throughout the universe there are pieces of earth-like or rocklike materials travelling at high speeds. We call them *meteoroids* (ME-te-or-oids), and if they are very small, we call them micrometeoroids (ME-te-or-ites). Astronomers have calculated that some 90 billion meteoroids enter the earth's atmosphere every second. Most of these are exceedingly small, about the size of a grain of sand you would find on the beach. Others are as large as a tenth of an inch or the size of the letter "o" in this sentence. Very few are large enough to survive their speedy trip through the atmosphere and reach the earth, because as they travel through the air, they hit the atoms in the air. This creates heat and the meteoroids burn.

Meteoroids travel at very high speeds, up to 160,000 miles per hour. At that speed, many of the small ones might vaporize and disappear when they hit the surface of a spaceship though they could damage it. Larger ones might dent or even tear a hole in the ship's metal surface. Therefore, some engineers believe that a spaceship should have more than one shell or layer—one ship inside another.

Some meteoroids are very large, weighing up to several thousands of tons. These larger ones, when entering the earth's atmosphere, are known as *meteors*. Those that actually land on the earth are called meteorites. If they were to hit the spaceship in flight, they would destroy it. However, these are very rare.

There is only about one chance in ten thousand that a spacecraft in flight from the earth to the moon would encounter a

meteoroid large enough to penetrate its skin. However, the tiny micrometeoroids can weaken the skin even though they cannot penetrate it, and they can damage some of the delicate instruments on a spacecraft. Some spacecraft have meteoroid shields to protect at least part of them.

The Worlds Beyond Our World

What is the solar system?

The heavenly body with which we are most familiar is the earth. It is one of the nine major planets that revolve about the sun. A *planet* (PLAN-et) is a heavenly body which revolves about a sun. It shines not because of its own light but by the reflection of light from the sun. For example, if you took a lighted electric bulb, it could resemble our sun. Then if you placed a mirror-surfaced ball near it, you would see that the ball was lighted. Actually, the ball is only reflecting the light from the electric bulb.

In addition to the planets there are perhaps 100,000 *planetoids* (PLAN-et-oids), also called *minor planets* or *asteroids* (AS-ter-oids). They differ from the major planets, such as the earth, mainly in size. The largest of these is Ceres, which has a diameter of about 480 miles or about the same size as the whole of France. Most of the asteroids are small, only about a few miles across, and some are only two feet in diameter.

The next most familiar heavenly body to us is our moon. It is a *satellite* (SAT-el-lite) or a heavenly body that revolves around a larger one in much the same way that the earth is a satellite of the sun. Six of the nine major planets have one or more satellites, or moons, revolving around them. While the earth has only one moon, the planet Jupiter has thirteen.

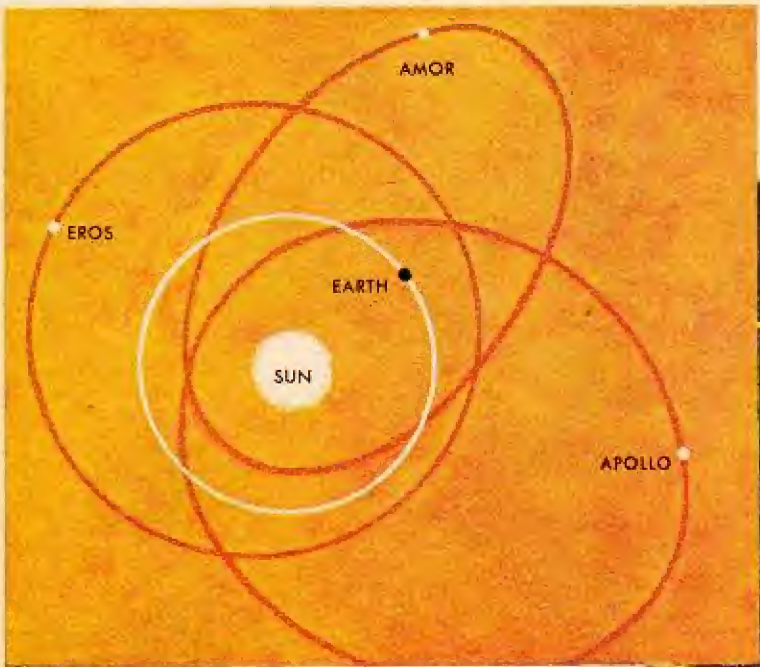
Also revolving around the sun are a number of *comets* (COM-ets). The typical comet has a head and a tail. It is thought that the head consists of a mixture of gases and small solid particles similar to meteorites. The tail is comprised of many gases. The comet glows and reflects sunlight as it moves through the heavens.

Many of the comets revolve around the sun in the same manner as the planets, while others come from some distance away in the universe, pass around the sun and then disappear.

Together, the major planets, their satellites, the asteroids, comets, meteorites, and our sun form the solar system.

This solar system together with the millions of stars that surround it form our *galaxy* (GAL-ax-y). The galaxy in which we live is called the Milky Way. If we join our galaxy with all the other many millions of galaxies, we then have the universe.

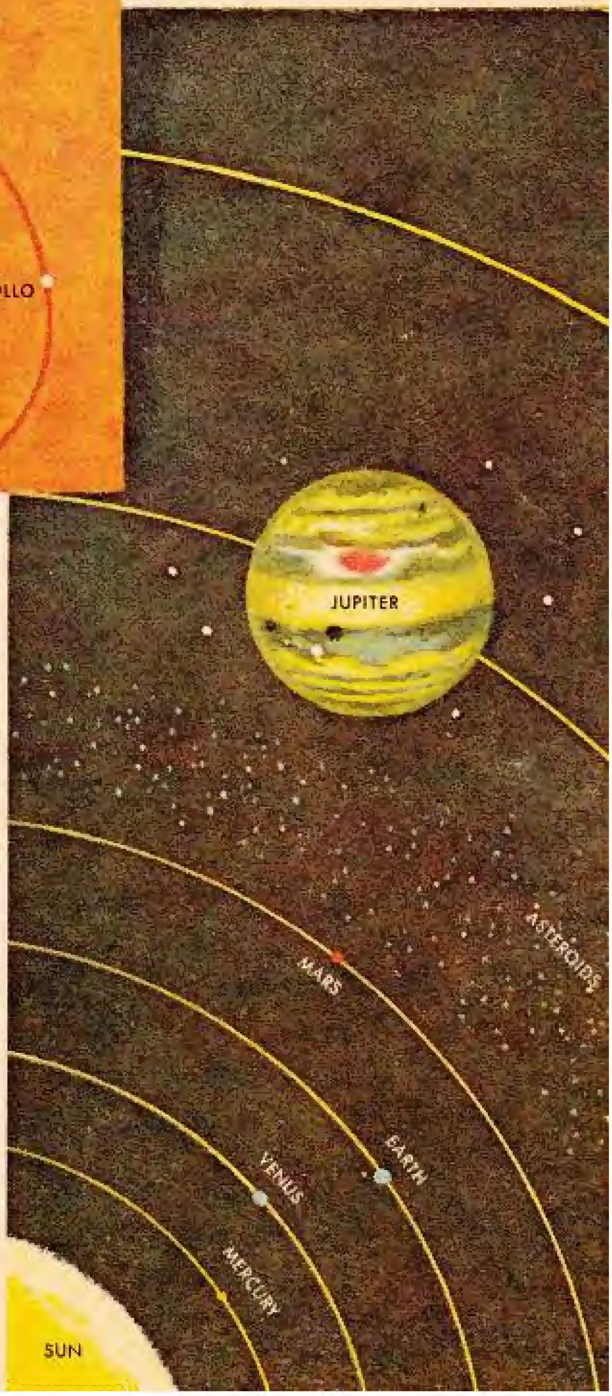
from you. The same is true of the sun and earth even though there is no string between them. As the earth and the other planets travel around the sun, they are pulling away from the sun. However, there is another force that is "pulling" on the earth—that is gravity (GRAV-i-ty).



The asteroids that lie between the orbits of Mars and Jupiter revolve about the sun in elliptical orbits just as the planets in our solar system do.

Why do the planets revolve about the sun?

If you were able to stand in space millions of miles above the North Pole and observe our solar system, you would find all the planets circling about the sun in a counterclockwise direction, like the hands of a clock running backwards. Why do the planets follow this pattern? If you've ever flown a model aeroplane in a circle, while holding it with a string, you already know the answer. If you take a model aeroplane tied to a string, and let it fly in a circle around you, you will find that as long as the aeroplane travels at the same speed, it stays in the same path and it stays the same distance

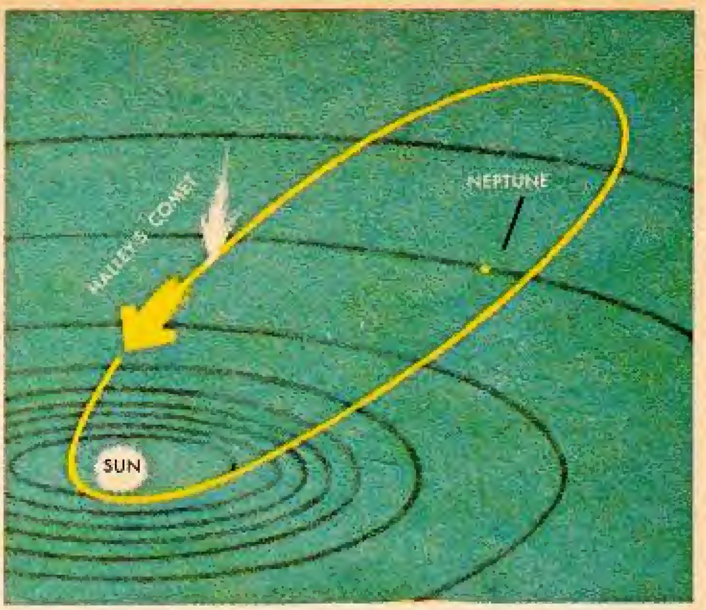


There are nine planets, including the earth, revolving about the sun.

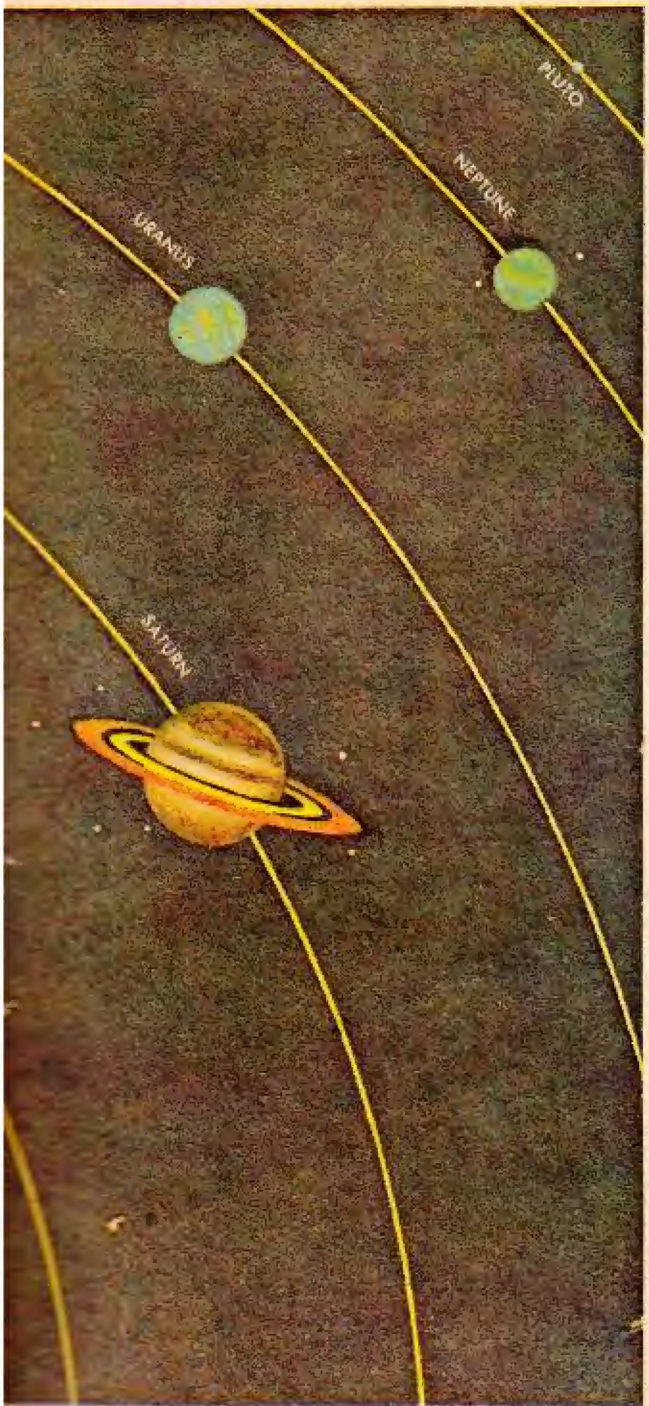
The sun's gravity pulls on the earth and the planets in the same way that the earth's gravity pulls on you. All bodies in the universe have a gravitational attraction on each other.

How does gravity work?

Gravity is forever exerting its pull. If you throw a ball into the air, it falls to earth because of the pull of gravity. In the seventeenth



Halley's comet orbits around the sun once in 76 years and it will be visible over the earth in 1986.



century, Sir Isaac Newton of England discovered what we call the "laws" of gravity. He found that all bodies in the universe have an attraction power, and that the force of gravity depends upon several things. First, the greater the amount of matter or weight of a body, the greater is its gravity pull. For example, the earth has a greater gravitational pull than the moon, just as the sun has a greater gravitational pull than the earth. Second, Newton found that the distance between the bodies affects the strength of this force. Thus, gravity has a stronger pull when the two bodies are closer together than when they are farther apart.

How does *rotation* differ from *revolution*?

Did you ever spin a top or a gyroscope? As the top or gyroscope turns round and round rapidly, it is rotating (ro-TA-ting). Astronomers know that all the planets, including the earth, rotate around their own axis, or an imaginary line drawn through the centre of the

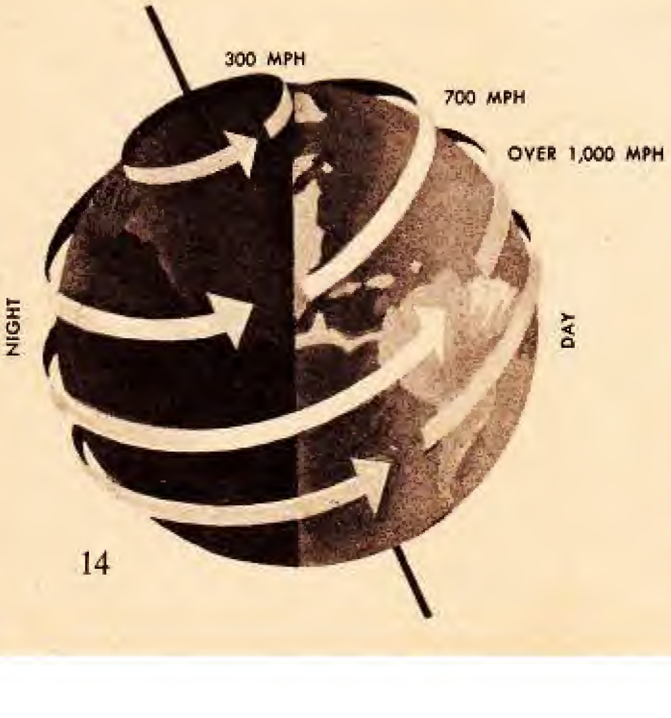
earth from the North Pole to the South Pole. It is this rotating motion that causes night and day. As the earth spins on its axis, part of it faces the sun and the other part faces away from the sun. One complete rotation takes twenty-four hours or a day. At times, we refer to half a rotation as daytime and the other half as nighttime.

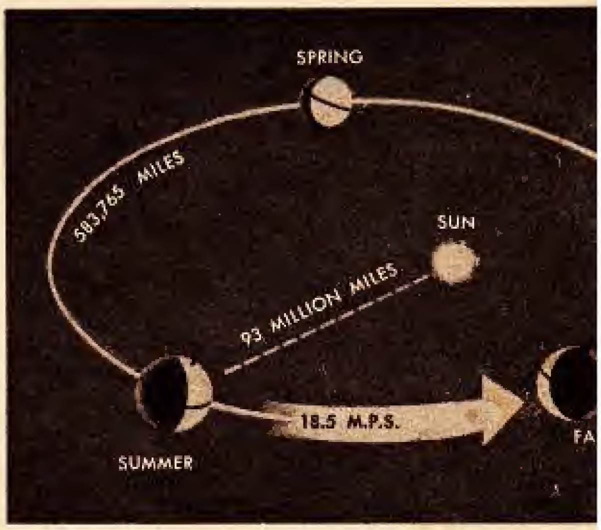
Hold a ball in your hand between the thumb and index finger. At the point where the thumb touches the ball, picture the South Pole, and where the index finger touches the ball, the North Pole. Put a chalk mark halfway between the poles. This will be the equator or middle of the earth. Now place another chalk mark near the North Pole. As you rotate the ball and make one complete turn, you will see that the mark at the equator has to travel a bigger distance than the mark near the pole. In other words, the mark at the equator has to travel faster than the mark near the pole since it covers a longer distance. This is also true on earth. In New York and Chicago, for example, the earth's speed amounts to 700 miles an hour or 12 miles a minute. At the same time that the earth is rotating, it is also moving around the sun. This movement is called *revolution* (rev-o-LU-tion). One complete trip around the sun is one revolution, or, as we know it, one year. To make this trip the earth travels at a speed of $18\frac{1}{2}$ miles per second. In one hour it covers more than 66,600 miles in space on its orbital trip around the sun.

What is a planetary orbit?

The planets revolve about the sun in a planetary orbit; that is, they move in an ellipse (el-LIPSE) or elongated circle. To draw an ellipse, stick two drawing-pins into a piece of cardboard about four inches apart. Make a loop of string about four inches long and slip it over the tacks. The loop should not be too taut. Stick a pencil point through the loop and stretch the loop out. Then, holding the pencil in

The earth's rotation results in day and night as parts of the earth face toward or away from the sun. The earth's revolving in an elliptical orbit about the sun results in the four seasons of the year.





this fashion, move it along the string and draw on the cardboard. You have now drawn an ellipse.

The points where the drawing-pins are placed are called the focal points of the ellipse. It was the German astronomer Kepler who proved that the planets revolve about the sun in an elliptical or planetary orbit and that the sun is located at one of the focal points.

The earth, like the other planets, travels about the sun in an elliptical orbit. At its nearest point, or *perihelion* (per-i-HE-li-on), the earth is 91.4 million miles away from the sun. At its farthest point, or *aphelion* (a-PHE-li-on), the earth is 94.6 million miles from the sun. The average distance between the earth and sun, according to astronomers, is 93 million miles.

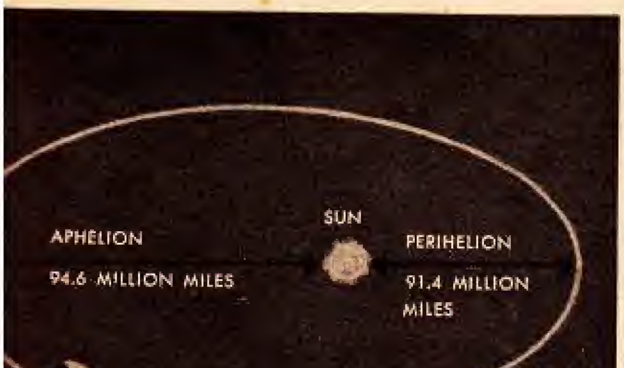
What is the asteroid belt?

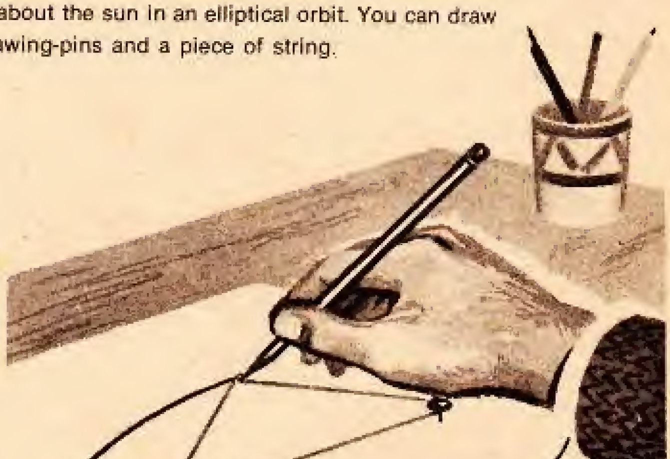
Between the orbits of the planets Mars and Jupiter is a space some 350 million miles wide. For many years, astronomers thought that there should be a planet in this space because it was so large and it left a gap in what they considered the normal spacing between planets. In 1801, astronomers found a heavenly body only about 480 miles wide. They watched it through their telescopes and found that it revolved around the sun like a planet. Several years later they discovered many more "small planets" in this portion of the sky.

Today, we know this region as the asteroid belt. It is believed to include more than 100,000 planetoids or asteroids. Some are ball-shaped, like the earth, while others are like irregular chunks of rock. The largest of the asteroids is Ceres, 480 miles in diameter. Other known asteroids are much smaller. Adonis, Apollo and Hermes are only about a mile or less in diameter.

Between these asteroids and the sun are the *inner planets*—Mercury, Venus, Earth and Mars. The planets beyond the asteroids—Jupiter, Saturn, Uranus, Neptune and Pluto—are known as the *outer planets.* (See illustration, pages 12-13.)

The earth, like the other planets and asteroids, revolves about the sun in an elliptical orbit. You can draw these orbits of our solar system, using a pencil, two drawing-pins and a piece of string.



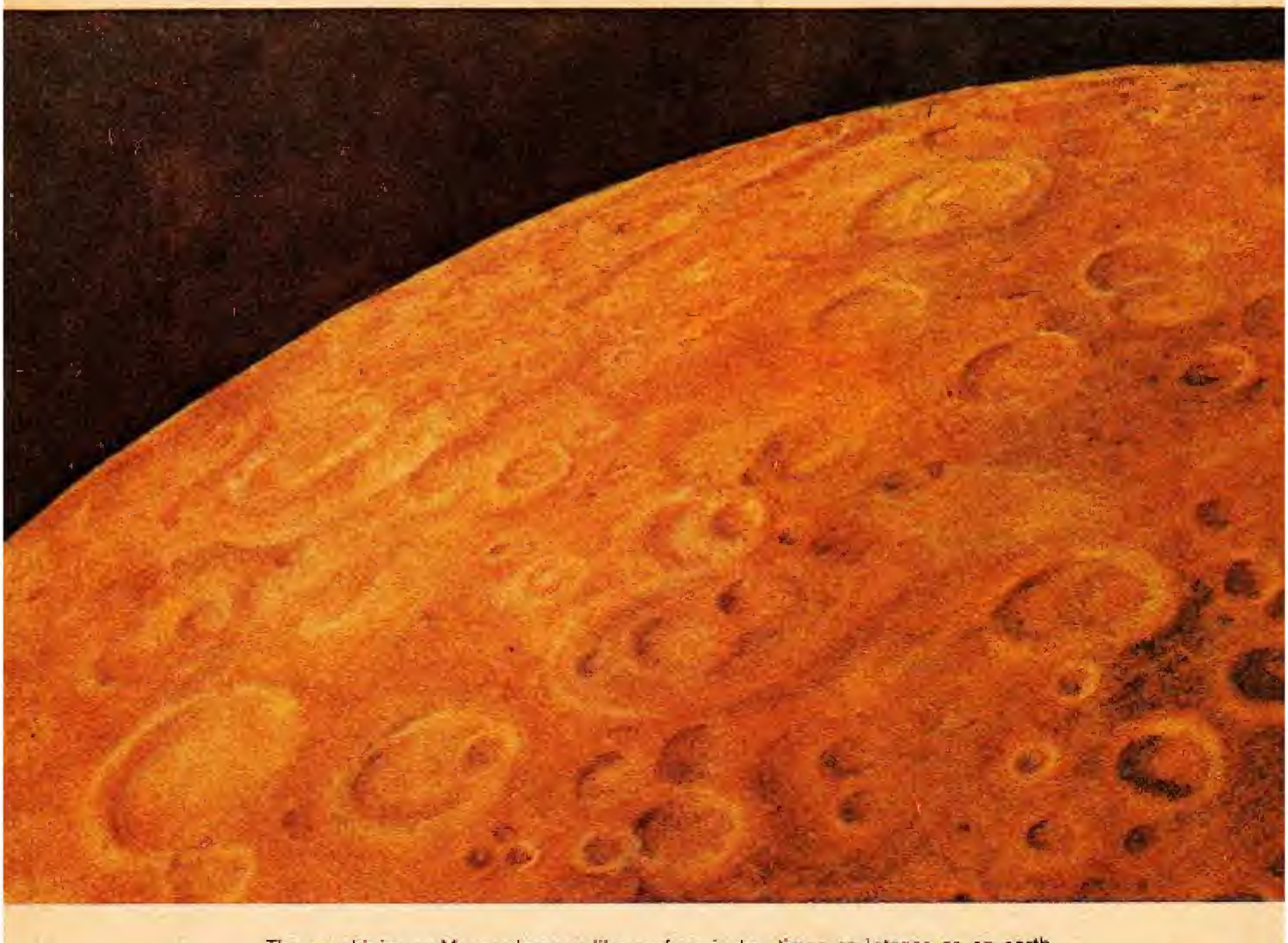


Why will it be difficult to explore Mercury?

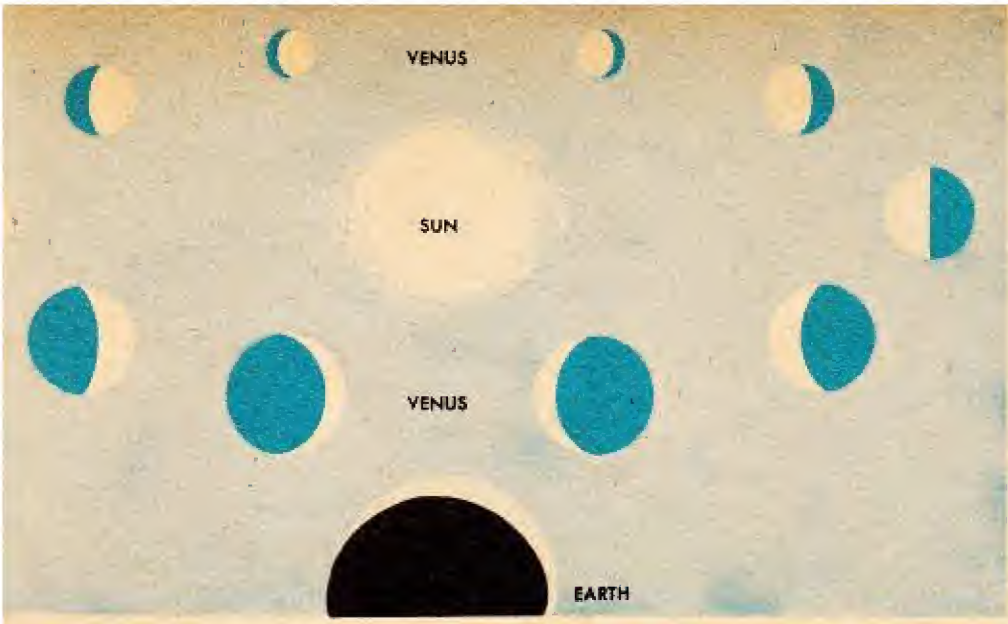
Mercury, the nearest planet to the sun, is also the smallest. It is only slightly larger than our moon—3,000 miles in diameter compared with 2,160 miles for the moon. In spite of its small size, its gravity is not as low as might be expected. A person weighing 100 pounds on the earth would weigh 40 pounds on Mercury, but he would only weigh 17 pounds on the moon.

A recent Mariner space probe flew close to Venus and Mercury, and sent back the first close-up pictures of Mercury. These show that the planet's surface is covered with craters very like the moon. The surface can be photographed clearly because Mercury's atmosphere is very thin. It contains the gases argon, neon and helium, but no water has been detected. There are no clouds surrounding the planet.

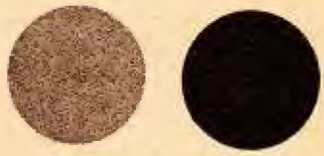
Mercury's year, that is the time it takes to orbit the sun, is only 88 earth days long. It rotates very slowly on its axis so that its day is 176 earth days long—twice as long as its year. The side of the planet facing the sun is very hot because Mercury is so near to the sun. On Mercury, the sun appears ten times as bright as it does on earth. The temperature there can be as high as 510°C, hot enough to melt lead, while on the side away from the sun the temperature drops as low as −210°C. Most of our atmosphere would be liquid or frozen at this temperature.



The sun shining on Mercury's moon-like surface is ten times as intense as on earth.



Like our moon, the planet Venus has phases. It appears as a thin crescent when nearest the earth.



What will we find on the planet Venus?

Venus, the nearest planet to us, is about the same size as the earth and is sometimes called our "sister planet." At its nearest point it is only 26 million miles from the earth. It is the brightest of all the planets as seen from the earth because it is so near, and because it is surrounded by thick white clouds which reflect the sunlight. These clouds have prevented us from learning about the planet below them until space probes were sent to it. They have flown past, orbited and even landed on the surface, sending back pictures and information to earth.

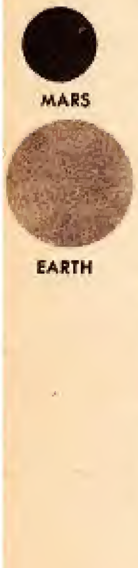
The clouds form a layer about 18 to 25 miles thick, with their tops possibly 90 miles above the surface, and clear atmosphere below them. Earth's clouds are mostly less than 6 miles from the surface and very thin in comparison. These Venusian clouds are mainly composed of carbon dioxide, with only traces of the water vapour, oxygen and nitrogen that make up most of our atmosphere. The clouds move very quickly, rotating perhaps 50 times as fast as the planet itself.

Venus turns very slowly on its axis, taking 243 earth days for one complete rotation, and it rotates in the opposite direction to the other planets. Scientists can only speculate on why it should do this. It takes 225 earth days to travel around the sun.

Space probes have measured the surface temperature on Venus to be approximately 475°C. This is only a little cooler than Mercury, which is much nearer the sun, and the temperature does not seem to vary much over the surface. Another unexpected piece of information, sent back by the space probes, was the very high surface pressure, about the same as that 2,400 feet down in the Atlantic Ocean. Scientists were surprised by the first pictures of the surface of Venus sent back by the Russian space probe, Venera 9, in October 1975, which showed that there was enough light to see the surface at quite a distance from the spacecraft. It had been thought that the clouds stopped most of the sunlight from reaching the surface.

Perhaps there is life on the 'Red Planet'.

Is Mars another earth?



Mars has always attracted a lot of attention, partly because of its red colour which gave it its name, after the god of war. Astronomers have been able to learn more about its surface than any other planet, but recent Mariner space probes have been able to tell us even more about Mars. One of these, Mariner 9, went into orbit around the planet, and photographed the whole surface. We now have a complete map of Mars, showing that the so-called "canals," apparently seen by some astronomers through telescopes, were only optical illusions.

Mars has several similarities to earth. It rotates at about the same speed, its "day" is about 24 hours 37 minutes of earth time, and its axis is tilted at about the same angle as the earth, so it has seasons in the same way as we do. It also has polar "ice caps" which can be seen to shrink and grow with the changing seasons. On the other hand, Mars is only about half the size of the earth, and its year—it takes 687 earth days to revolve around the sun—is twice as long as earth's. It is 142 million miles from the sun compared with the earth's 93 million miles, and the sun is only half as bright seen from Mars. So, although the temperature can be as high as 27°C at the equator, it can fall as low as −123°C at the poles.

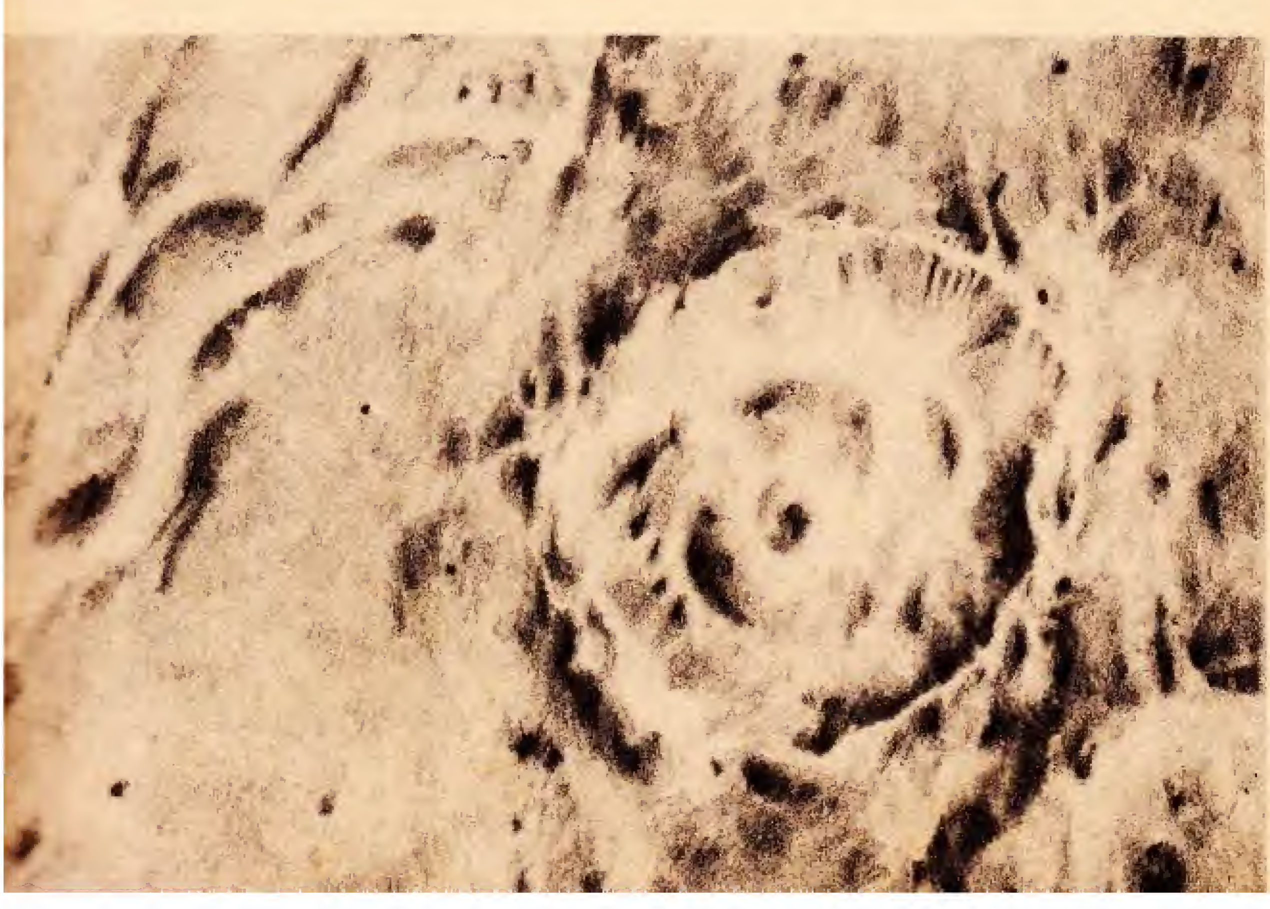
The photographs taken by Mariner 9 show that Mars has a very dusty surface,

covered with craters similar to those on the moon. It also has earth-like features such as volcanoes, canyons and dry "riverbeds." These indicate that although Mars is now very dry, there may have been water or some other liquid flowing on its surface at some time. The dust is often whipped up into storms by very fierce winds, and these dust storms can hide the whole surface of the planet. The storms appear to occur more often during the Martian summer and most scientists think that they could explain the variations in colour of the planet that have been seen by astronomers. These colour changes had led some people to believe that there might be life on Mars. The Martian atmosphere is very thin and is composed mainly of carbon dioxide. It has traces of water vapour, but there is no oxygen and little or no nitrogen.

Man has often speculated about life on Mars. Some scientists had argued that the "canals" were irrigation channels built by intelligent Martians, but if life does exist on Mars it will probably not be large man-like creatures. Man requires water and oxygen in order to survive, and our atmosphere protects us from the sun's harmful ultra-violet radiation. Mars has no oxygen in its atmosphere and, although there may be ice in the polar caps, below a layer of frozen carbon dioxide, there is no liquid water on the surface and very little water vapour in the atmosphere. The ultra-violet radiation reaching the surface of Mars would harm most of the animal and plant life that we know on earth. However, this does not mean that life cannot exist on Mars. There may well be forms of life that have adapted to the conditions on Mars in the same way that we have evolved to fit in with the conditions on earth.

The Americans have launched a space probe to orbit Mars and send down a craft to land on the surface. Part of its task is to detect any life that might be there. So we may soon have an answer to the old question of life on Mars.

The cratered Martian surface is sometimes completely hidden by dust storms.



What is Jupiter made of?

Jupiter is the largest of all the planets, containing more matter than all the other planets combined. It is almost like a small solar system itself as it has 13 moons, two of which are as big as Mercury and two the size of our moon. The outer four orbit Jupiter in the opposite direction to the rest, and originally they may have been asteroids. Jupiter spins faster than the other planets taking only about 10 hours for one rotation. It takes about 11 years 10 months to make one complete revolution around the sun.

Our ideas about Jupiter have been changed recently by the information and pictures sent back by two Pioneer space probes which flew close by the planet. These flew on past Jupiter and Pioneer 10 will eventually become the first man-made object to leave the solar system. Pioneer 11 will pass close to Saturn in 1979, hopefully giving man his first close-up view of that planet. The probes showed that below its atmosphere, Jupiter is a liquid planet with perhaps a tiny rocky centre. The elements that make up most of Jupiter are hydrogen and helium, just like our sun. Jupiter's atmosphere is also mainly hydrogen and helium, but contains cloud layers of ammonia crystals with possibly ice crystals and water droplets.

The top of the cloud layer, about 150 miles above the liquid surface, is very cold with a temperature of −122°C, but both the temperature and the pressure increase towards the centre of Jupiter. It is thought that the temperature could be as much as 30,000°C at the centre of the planet and that the pressure there is millions of times greater than on the surface of the earth. With all this heat inside, Jupiter gives off more heat than it receives from the sun. In fact, if it had been a bit larger, the pressure and temperature would have been great enough to start a nuclear reaction at the centre and it would have been a sun itself.

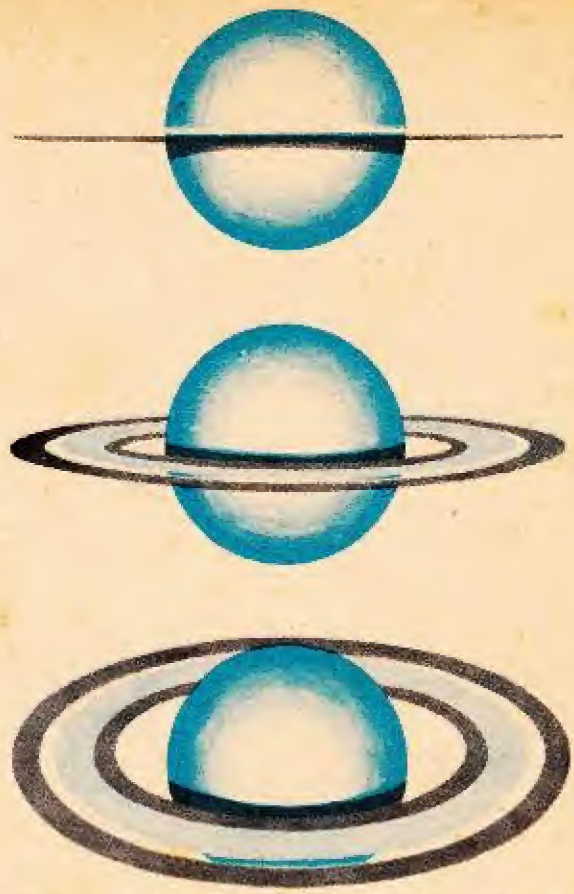
All we can see of Jupiter is the top of its clouds, with their alternate light and dark bands reaching right around the planet, and the famous Red Spot interrupting these bands. The Red Spot, which is much larger than the earth, appears to be a violent storm which has been raging for centuries. It is thought to be like a whirlpool with its top rising

Jupiter, the largest and the fastest-rotating planet, completes one rotation in less than ten earth hours. It is so far from the sun, however, that it takes almost twelve years to make one complete revolution around it.

above the surrounding cloud level.

The Pioneer probes found that Jupiter's radiation belts are much more intense than those of earth. In fact the radiation is 100 times stronger than that which is necessary to kill a man, and is almost strong enough to put a space probe out of action.

Although Jupiter may seem the last place to find life, this is not altogether impossible. The planet contains the basic elements essential to primitive life forms and, somewhere between the extremes of temperature and pressure, suitable conditions may occur for life to develop.



The rings of Saturn, visible only through a telescope, appear at different angles each year. When they are tilted toward earth, Saturn's brightness increases.

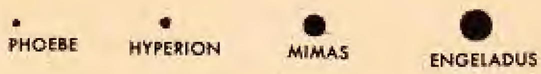
What lies beyond Saturn's rings?

Saturn is similar to Jupiter in many ways and is the second largest planet. Like Jupiter, it probably consists mostly of hydrogen and helium, but scientists do not know if it has a solid centre. Its clouds, which again are all we can see of the planet, contain methane and ammonia and form dark "belts" and light "zones", similar to those of Jupiter. They rotate about the planet at different speeds.

Saturn is almost twice as far as Jupiter from the sun and so little of the sun's heat or light reaches it. The surface temperature is believed to be about −176°C, and it is possible that Saturn too gives out more heat than it receives.

Like Jupiter, Saturn rotates quickly. Its day is just over 10 hours of earth time. Its year, or time for one complete revolution around the sun, is about 29½ earth years.

Saturn was thought to have 9 moons, but in 1966, scientists saw what they think is a tenth moon, Janus, near the planet. It is too small and too close to the planet, however, for them to be absolutely sure. The largest of Saturn's



Comparison in size of Saturn's moons with our moon.

moons, Titan, is about the size of Mercury and has its own atmosphere.

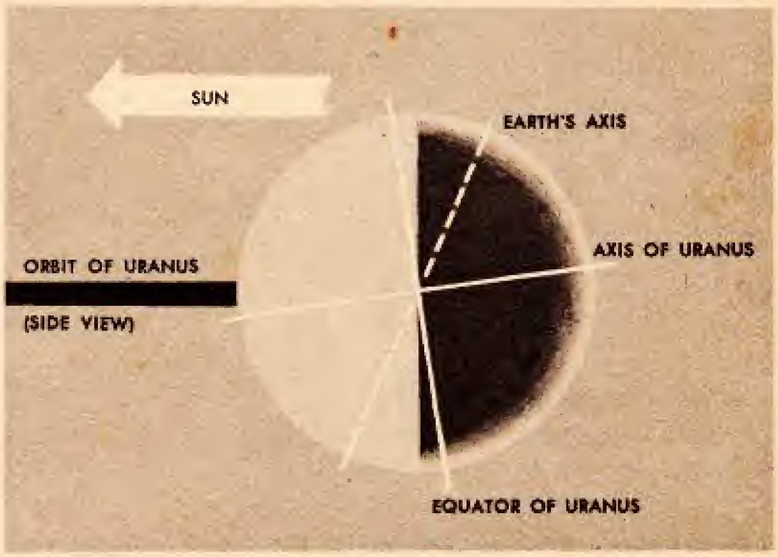
The most striking feature of Saturn is its rings. They look like a huge but very thin disc that appears to cut the planet in half through its equator, as you can see in the picture. They were first seen by Galileo in 1610, but were not identified as rings until 1655. The rings, which are much brighter than the planet itself, are probably composed of millions of small solid particles and ice crystals. There appear to be several distinct rings with divisions between them, and they may reach down to the planet's atmosphere. The whole ring system is 170,000 miles across compared with the planet's diameter of about 71,000 miles. The most recent measurements of their thickness indicate that they are almost certainly less than 6 miles thick—indeed stars can sometimes be seen through the rings.

A lot less is known about Saturn than about Jupiter as it is twice as far from us, but the Pioneer 11 probe sent to Jupiter will rendezvous with Saturn in 1979, and will, if still operating, send back pictures and information on this giant planet.

Where is our sun only a brilliant star?

When first seen by astronomers in 1690, Uranus was thought to be a star. It was not until 1781 that Sir William Herschel of England discovered that Uranus was a planet that revolved about our sun just as the earth does. Uranus is twice as far as Saturn is from the sun or twenty times that of the earth from the sun. From that faraway distance, we believe that our sun looks like a bright star in the sky.

Unlike all the other planets, Uranus rotates on an imaginary axis that almost points directly at the sun. It would be much the same as if our earth were turned so that the North Pole would be almost pointing at the sun. In rotating on this axis, the north pole of Uranus faces the sun for almost twenty years. Then as the planet revolves around the sun, the



The rotation of Uranus on its axis makes the sun appear to move over each pole in turn during its journey around the sun. With the other planets the sun's apparent motion stays close to the equator as they move around the sun.

rays of the sun move over the equator and shine over the south pole of Uranus for about twenty years. Because of its great distance from the sun, little heat reaches that planet. The surface temperature is believed to be about −218°C.

Although Uranus is four times larger than the earth, it is not as dense or as heavy as the earth. Its surface gravity is slightly less than the gravity on earth. It probably consists mainly of hydrogen and helium with methane and ammonia clouds like Jupiter and Saturn.

How did gravity help astronomers discover Neptune?

After Uranus was discovered, astronomers were puzzléd by its orbit around the sun. They knew that all heavenly bodies have a gravitational attraction or pull. Both the French astronomer Urbain Leverrier and the Englishman John C. Adams decided that there must be another planet beyond Uranus that was attracting it with its gravitational pull. Only in that way could the orbit of Uranus be explained. In 1848, the German astronomer Johann Galle located the new planet, Neptune, with his telescope exactly where Urbain Leverrier had predicted it would be.

Neptune is the outermost of the four "gas giants" and is more than three times larger than the earth. Its surface gravity is almost one-and-a-half times greater than on earth—and is greater than any planet's surface gravity except Jupiter's. Astronomers believe that the temperature on Neptune's surface is about −228°C.

The four large outer planets, although they all appear to contain the same gases, fall into two pairs. Uranus and Neptune are smaller and colder than Jupiter and Saturn. They are too far away for us to do more than guess about

their structure—whether they are gas, liquid, or whether they have a solid centre.

Neptune has two moons. The larger, Triton, is big enough to have an atmosphere, but it is too far away for us to be sure. As far as we can see, Triton is similar to the outermost planet, Pluto, in appearance. It has been suggested that Pluto may have been one of Neptune's moons long ago, before breaking away to orbit the sun.

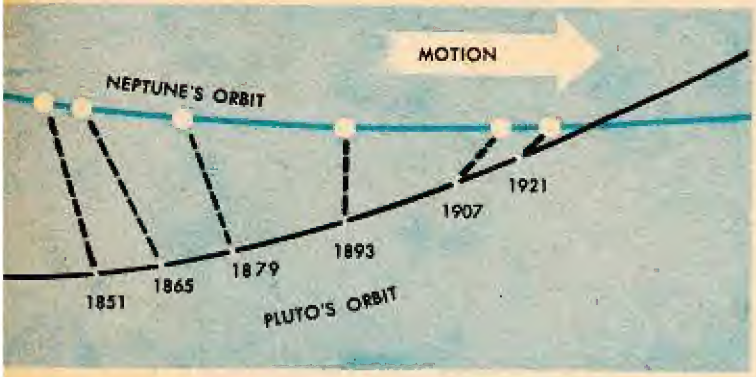
Why is Pluto called Planet X?

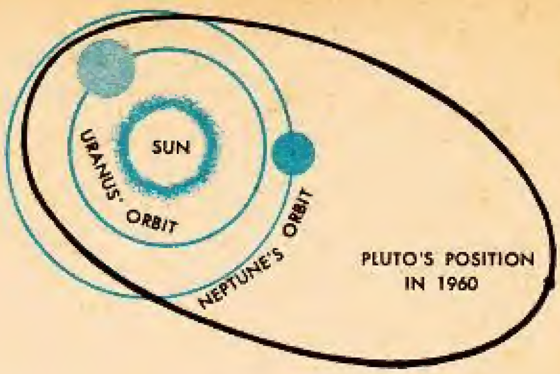
After Neptune was discovered, astronomers found that they still could not fully explain the orbit of Uranus. There had to be another heavenly body which was exerting a gravitational pull on Uranus so that it followed its strange orbit around the sun. A search was begun to find the missing planet. The letter X, used by mathematicians to signify an unknown quantity, was used as the name of the missing planet during the search.

In 1900, the American astronomer Percival Lowell started on his long search for Planet X. He directed much of the search and, finally, in 1930, the missing planet was found by Clyde Tombaugh. This planet was labelled "PL" for Percival Lowell and was called Pluto.

Pluto is amazing in many ways. It is

Both Pluto and Neptune revolve about the sun, but their orbits overlap and their paths cross each other twice in one complete revolution. A collision is possible, but it is thought unlikely.





more than 3,500 million miles from our sun. Its year, or one revolution around the sun, takes more than 248 earth years. It is so far away from us that it appears as little more than a point of light even through the largest telescopes, so it is very difficult to measure its size or to find out much about it. It does seem to be somewhat larger than Mercury, however, and more like the inner planets in structure than its large neighbours.

In studying Pluto, astronomers found that its orbit cuts across Neptune's. Will they ever collide? Mathematicians have made very complicated calculations to discover whether a collision is likely in the near future. These have shown that the two planets will not get close enough to collide within the next 4½ million years.

How do astronomers measure distance?

Because of the very large distances they must measure in space, astronomers have developed special units of measure. In this way they can avoid using all those noughts, such as we encounter in measuring the distance of Pluto to the sun—3,500,000,000 miles. One of the basic astronomical units is a *light year.*

Light travels at the speed of 186,000 miles per second. In one day a ray of light travels over 16,000,000,000 miles. In one year it travels 5,888,000,000,000 miles. To the astronomer, this is one light year.

So instead of writing this number with all the noughts, the astronomer merely writes "one light year."

How far away are the stars?

The convenience of the light year unit of measure is readily seen when we start talking about distances to the stars. You have looked up into the sky at night and seen the stars. But what is a star? A star is a heavenly body that shines by its own light. That means it must be very hot to give off heat and light, just like our sun. Actually, our sun is a star; it is the nearest star to us—93 million miles away.

Aside from our sun, how far is the nearest star? That star, called Proxima Centauri, is almost 25 billion miles away. To the astronomer this is 4¼ light years.

The next nearest star is Alpha Centauri, 500,000 million miles farther away than Proxima Centauri. Alpha Centauri is in the constellation, or star group, known as *Centaurus,* and it has the same brightness as our sun. However, it is so far away that it appears as a mere dot in our sky.

What is a galaxy?

A *galaxy* is a cluster, or group, of stars. Our solar system is part of such a group, or galaxy, in which there are more than 100,000 million stars. The diameter of our galaxy is estimated to be 100,000 light years, and remember that each light year is almost 6 million million miles.

Is there life on the other planets?

More than a century ago, Joseph von Littrow, an astronomer in Vienna, suggested that we build many tremendous bonfires in the Sahara Desert in Africa. These fires would be a signal to any beings living on Mars. While the fires were never built, the speculation about life on Mars, on Venus and on the other planets has continued.

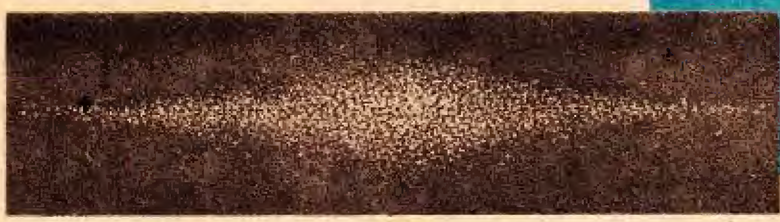
There are many people who believe that no intelligent, reasoning forms of life can exist in the choking atmosphere of Venus, or on the arid surfaces of Mars, or, in fact, anywhere else in our solar system. Others, however, feel that life in some form may exist, but it would certainly be different from the life forms we know on earth. Thus far, there has been no definite proof to support the views of either side.

Early in 1961, scientists at the National Institute of Health in Washington, D.C. announced that they had started to grow "life" that they believed came from another world. These "bugs," as they called them, were little twisted rods about eight- to sixteen-millionths of an inch long. They found this "life" inside a meteorite that fell at Murray, Kentucky in 1950. This "life," according to the scientists, was unlike anything we have ever found on earth.

Another group of scientists from Fordham University and Esso Research and Engineering Company in New York City announced at the same time that they, too, had found "other-world life." They discovered waxy compounds inside a fragment of a meteorite that fell near Orgueil, France in 1864.

Although there are some scientists who feel that these two findings are now

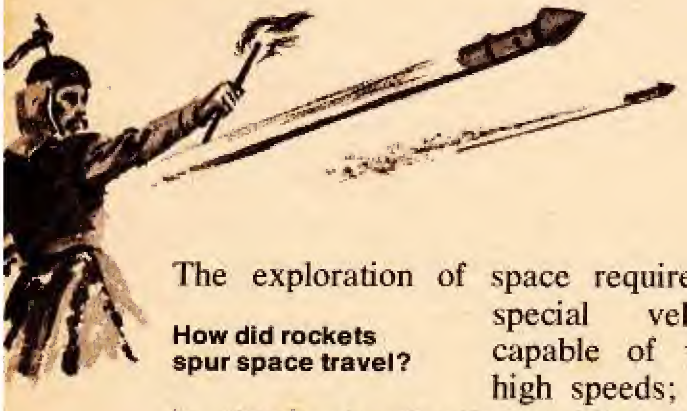
Our galaxy (our solar system and millions of stars) is a huge flat spiral about 475 thousand million miles long. Below, a side view, and at the right, a top view. The cross indicates the position of our solar system.



definite proof that life does exist elsewhere in the solar system, there are many others who do not accept these "proofs" of life. They feel that the waxy compounds are too similar to those we have on earth and that the meteorite became contaminated over the years, thus producing this strange substance. They also feel that the little twisted rods of life, which the Washington scientists presented, come from high up in our own atmosphere. Not until man is able to explore space more thoroughly and travel through it in his own spaceship, will he be able to obtain a definite answer about life on other planets.

Key to Planetary Exploration—the Spaceship

The Chinese used "war" rockets in A.D. 1232.

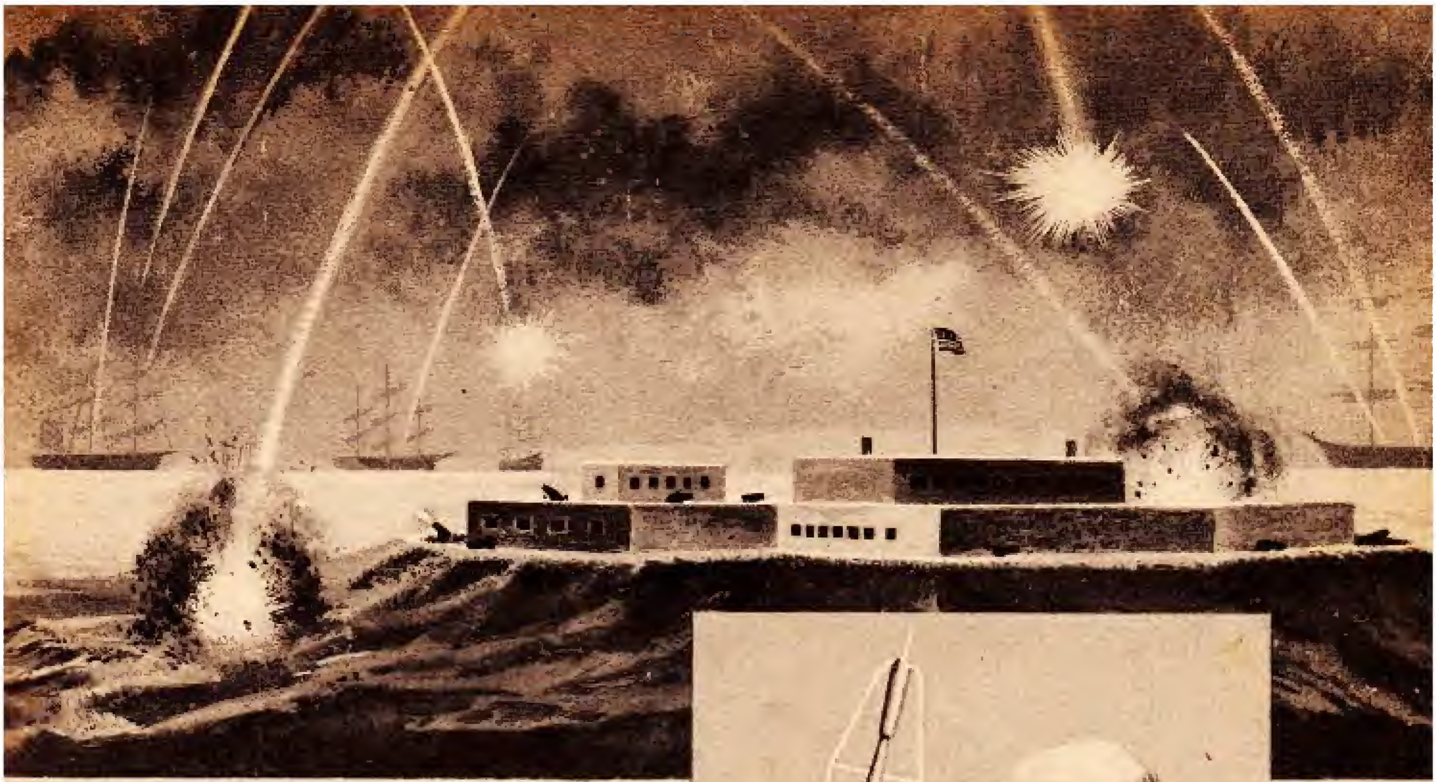


How did rockets spur space travel?

The exploration of space requires a special vehicle capable of very high speeds; that is, thousands of miles per hour. This space-exploring vehicle, or spaceship as we call it, is merely the next step after the giant rocket. Rockets have a long history of use for entertainment and war. Their greatest development came, however, when scientists realized that rocket power was needed to explore space and to enable spaceships to reach the moon and eventually the planets.

The earliest attempt to use rocket power to fly is supposed to have taken place more than 1,000 years ago in China. This early "spaceship" was a bamboo chair to which forty-seven rockets, or large firecrackers, similar to those shot into the air on Guy Fawkes' night, were attached. The pilot of this early spaceship was a Chinese mandarin named Wanhu. When the firecrackers were ignited, the chair was supposed to shoot up into the air. Unfortunately, when they were ignited, Wanhu and his "ship" disappeared in a cloud of smoke and flame.

In their attack on Washington, D.C. in 1814, the English used a war rocket, which was developed by Sir William Congreve. The American Army was routed and the British captured the capital. Several weeks later, these rockets were used during the British bombardment of Fort McHenry, near the city of Baltimore, Maryland. This famous event is referred to in the United States National Anthem, *The Star-Spangled*



"And the rockets' red glare, the bombs bursting in air . . ." was inspired by the British rocket bombardment of Fort McHenry in 1814.

Dr. Robert H. Goddard, father of American rocketry, built and fired rockets more than forty years ago.

Banner—"And the rockets' red glare, the bombs bursting in air . . ." The rockets failed this time and Fort McHenry did not surrender.

It was not until early in the twentieth century that serious and extensive work in rockets began. An American physicist, Dr. Robert H. Goddard, built and fired working rockets that soared many miles into the air. He wrote a long article about how rockets could be used to explore the upper atmosphere, which balloons could not reach. He even suggested that a rocket could be fired to the moon. Though Goddard is now considered the "father of the modern rocket," he was ridiculed for his ideas and his wonderful work was ignored in the United States.

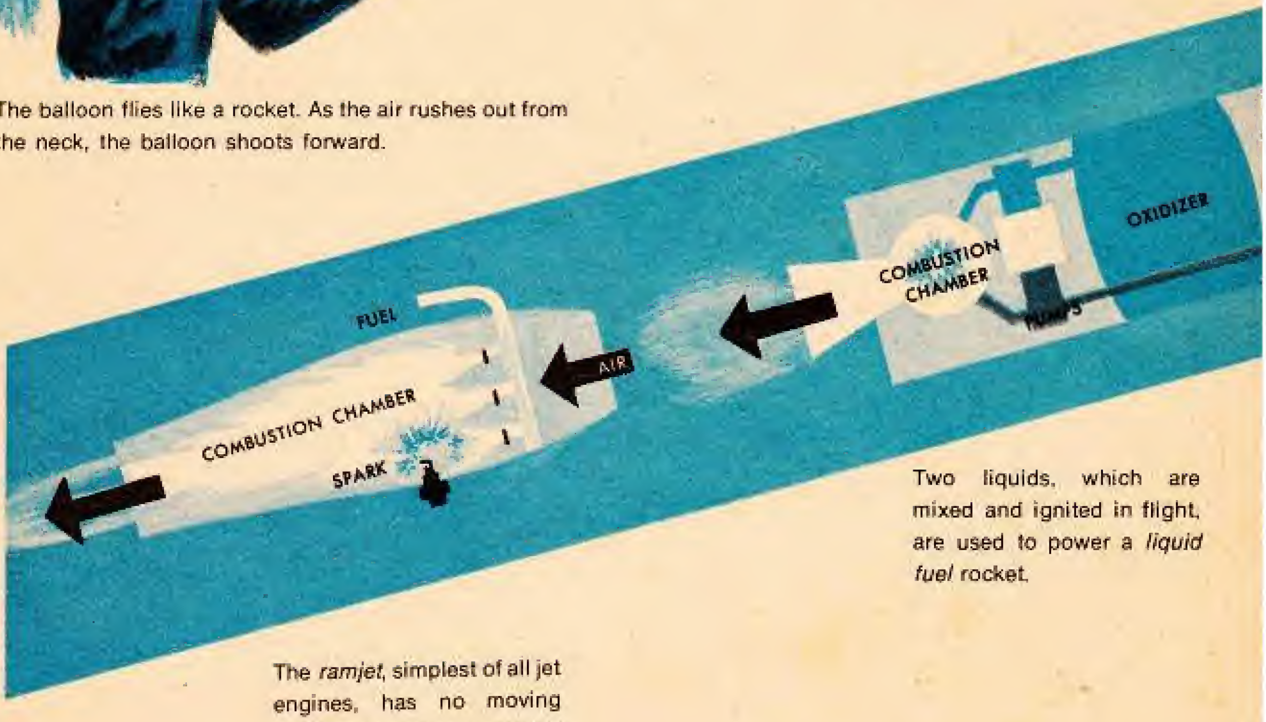
In Europe, on the other hand, there were a number of scientists who recognized the value of Dr. Goddard's work. Among them was Dr. Werner von Braun, a key figure in the development of the deadly German V-2 rocket, which was used to bomb London during World War II. Von Braun's knowledge and skill were used after the war by the United States in its rocket research programme at the Redstone Arsenal in Huntsville, Alabama.

The first true rocket-propelled space vehicle was fired on February 24, 1949. At that time, the United States Army sent up the first "two-stage" rocket at White Sands, New Mexico. They used a German V-2 rocket, which they had

The balloon flies like a rocket. As the air rushes out from the neck, the balloon shoots forward.

Why does a rocket fly?

Underlying the working of a rocket is a basic scientific rule — Newton's Third Law of Motion. It is named after Sir Isaac Newton, who was the first man to realize that these rules worked every time and everywhere in the world and even in the universe. Simply stated, this rule says that "for every action, there is an equal but opposite reaction."



Two liquids, which are mixed and ignited in flight, are used to power a *liquid fuel* rocket.

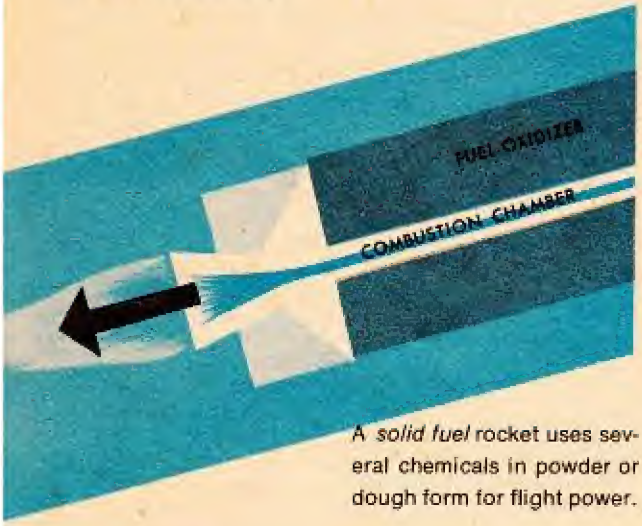
The *ramjet*, simplest of all jet engines, has no moving parts and must be in motion before it will work.

captured during World War II, and it carried a smaller American-made rocket, the *WAC Corporal.* At the exact second when the V-2 rocket reached its fastest speed, the *WAC Corporal* started its own motor. Thus, it added to the speed it already had. The V-2 rocket dropped off when its fuel was consumed, and the *WAC Corporal* rocket continued going higher and higher. It reached a height of 250 miles above the earth before it started to come down.

Newton's third law explains why a rifle "kicks back" when it is fired. The action of the bullet moving forward out of the gun produces an equal force in the opposite direction. You can test this rule, or law, yourself. Take a balloon and blow it up. When you release it, it will zoom away from you. The balloon flies away because the air inside rushes out of the small opening in the back. In other words, the forward motion is an equal and opposite reaction of the air

rushing out the back.

A rocket flies for the same reason. As hot gases, created by burning fuel, escape through the small opening in the rear of the rocket, they create an equal but opposite reaction which drives the rocket forward.

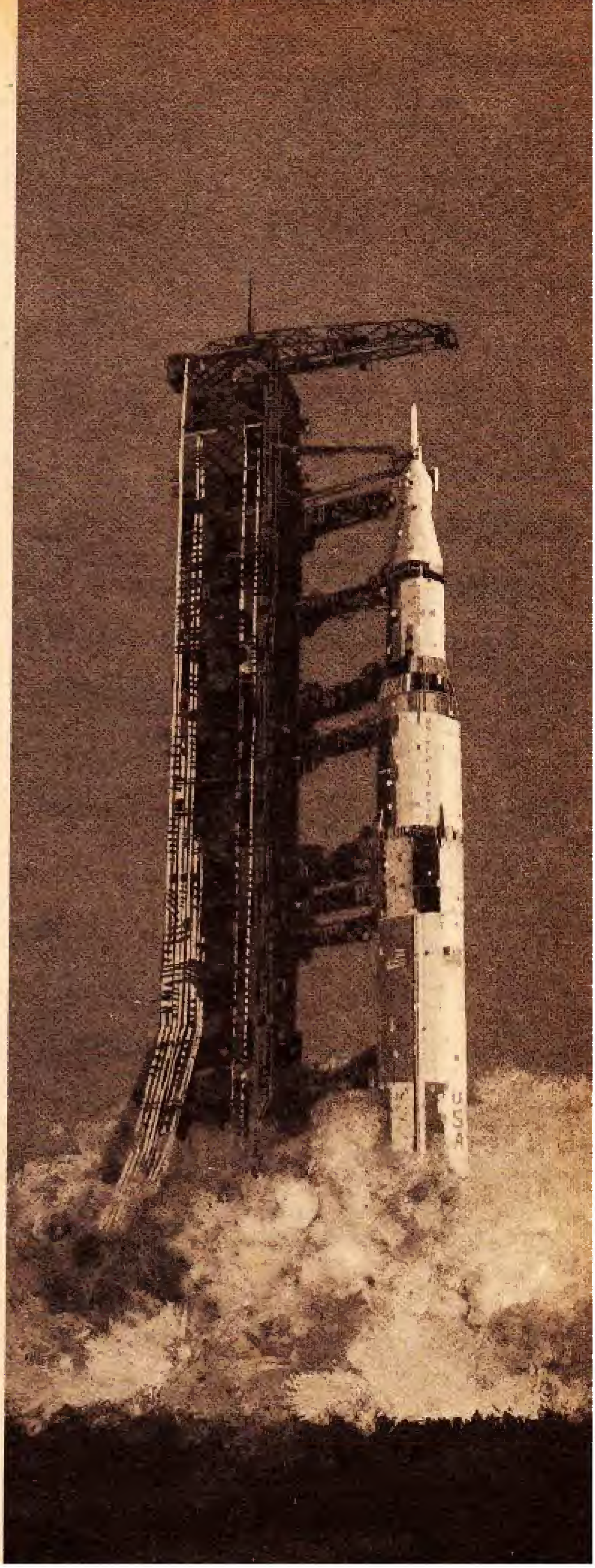


A *solid fuel* rocket uses several chemicals in powder or dough form for flight power.

Can a rocket fly in outer space?

All of you have seen an aeroplane winging its way through the sky. It is able to do so because we have an atmosphere; that is, nitrogen, oxygen, argon, carbon dioxide and other gases which surround the earth in the troposphere and stratosphere. The aeroplane needs the air, which is forced over and under its wings by the propeller, or through its jet engines, in order to help the plane rise and move forward. Without the atmosphere, the aeroplane would not be able to fly, and we know there is no atmosphere several hundred miles above the earth.

A rocket, on the other hand, because it works in accordance with Newton's Third Law of Motion, can operate more efficiently outside the atmosphere than within it. The atmosphere offers resistance, or pressure, against the forward moving rocket. You can test this resistance yourself on a windy day. Take a large piece of cardboard, about two or

The Saturn V rocket was used to put man on the moon.


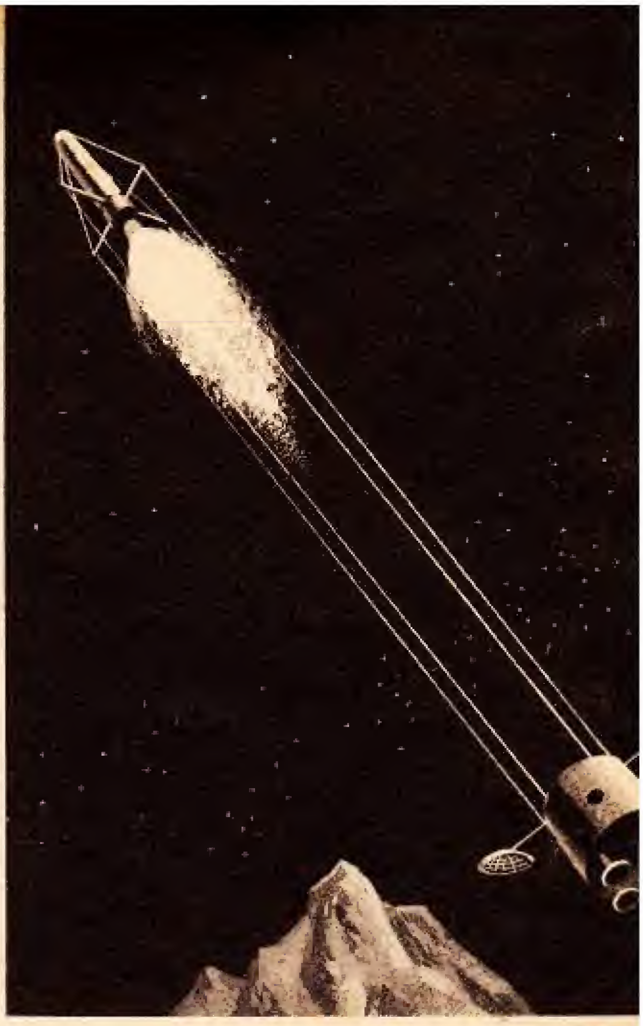
three feet square. If you hold it straight above your head and run into the wind, you will find that you feel a pressure against the cardboard; it may even pull your arms back somewhat. But if you hold the cardboard flat, so that only the thin edge faces the wind, you will find little resistance.

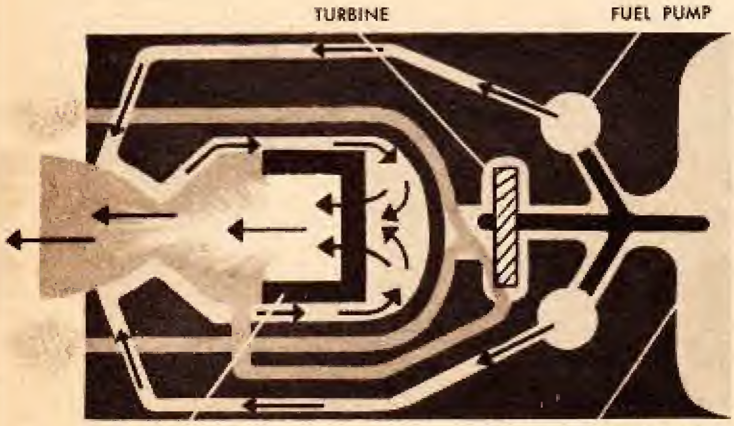
There is, however, a different problem which faces the rocket in space. To keep the rocket engine burning, there must be a supply of oxygen. There is oxygen, in gas form, in our atmosphere; it is the same oxygen that we breathe. In space there is no *free* oxygen, as scientists call it. Therefore, the rocket must carry its own supply.

What fuel does a rocket use?

The rocket's thrust, or forward speed, is created by the escape of hot gases through the rear openings or ports. These hot gases are created by burning fuel within the rocket. Basically, two types of fuel are used in rockets.

First, there is liquid fuel. This often consists of two liquids that are kept in separate tanks. When the two liquids are mixed and ignited, they vaporize or turn to gas. The gases expand when heated, and their only way to escape is through the rear openings. Two of the liquids commonly used are alcohol and liquid oxygen. The liquid oxygen is called *lox.*



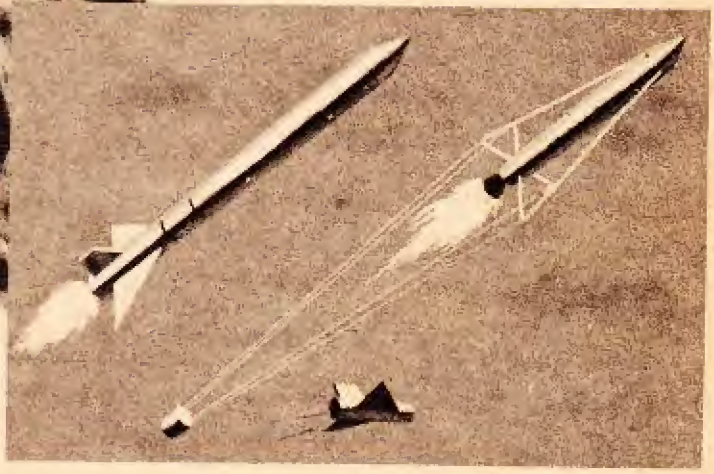


The oxygen is needed to support combustion or to enable the mixture to burn in space where no oxygen is available. Another liquid combination consists of high octane petrol and nitric acid. The nitric acid contains oxygen which permits the mixture to burn.

Second, solid fuels are used in some rockets. This fuel consists of a mixture of several chemicals in powder form. One of the chemicals in the mixture must contain oxygen, which is released as a gas when it is heated. Without this release of oxygen, the mixture would stop burning much in the same way as a candle will stop burning if you cover it tightly by placing an inverted water glass over it. The flame is snuffed out when its supply of oxygen is gone.

An atomic reactor and liquid hydrogen are used to power a *nuclear* rocket.

A nuclear-powered spaceship is today's dream of the space age. A nuclear motor is more efficient, developing greater thrust for its size than either liquid or solid fuel rockets. In plans for a nuclear-powered space trip to the moon, Mars or Venus, space engineers hope to use rockets to raise the spaceship above the earth's atmosphere. Here, the bottom stage would be detached and slide back to earth, while the smaller ship would speed ahead on its journey. The nuclear engine would be contained in front, and the men would travel in a gondola suspended by very long cables from the engine. In this way, the men would be better protected from the engine's radioactivity.



Can we use nuclear power for fuel?

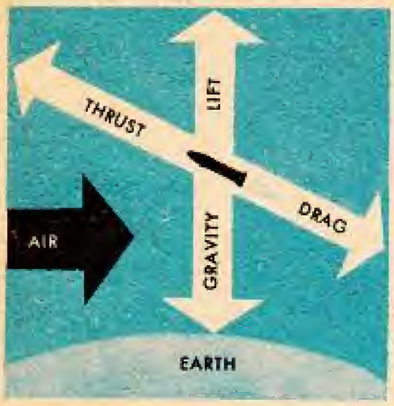
Scientists are experimenting with nuclear power, or atomic reactor engines, to replace the liquid and solid fuels used for rocket propulsion (the force needed to make a rocket fly). In a nuclear-powered rocket, the motor consists of an atomic reactor through which liquid hydrogen is pumped. As the hydrogen is heated by the atomic reactor, it turns into a gas and escapes through the rear ports of the rocket.

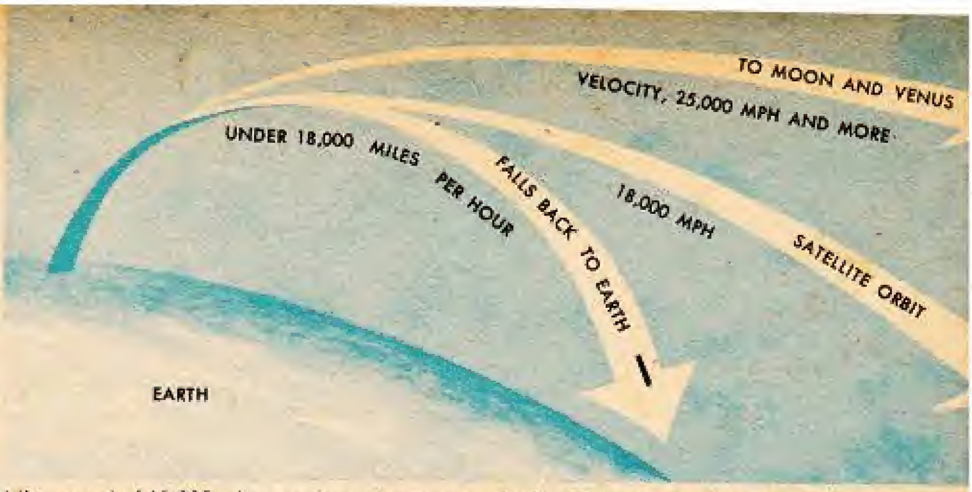
A nuclear engine, however, creates very high temperatures—more than 3490°C. This means that the motor section of a spaceship using a nuclear motor would have to be very well insulated from the rest of the ship, since a spaceman could not stand that extreme heat. Considerable work still has to be done before this type of motor can be used.

What is escape velocity?

The speed necessary to overcome gravity is called *escape velocity.* When a rocket is launched on the earth, it is pushed upward according to Newton's law of motion. It is, however, encountering two other forces. One is the normal pull of the earth, or the earth's gravity. The other is the resist-

A space vehicle in our atmosphere is affected by four forces. Its *lift* must offset *gravity*; its forward *propulsion* must overcome air resistance or *drag*.





At the speed of 18,000 miles per hour, the space vehicle's lift and propulsion are sufficient to keep it in orbit around the earth. To escape from the earth's gravitational pull, the vehicle must exceed 25,000 miles per hour.

ance of the atmosphere. Therefore, the rocket's forward thrust, or speed, must be high enough to overcome these two opposing forces.

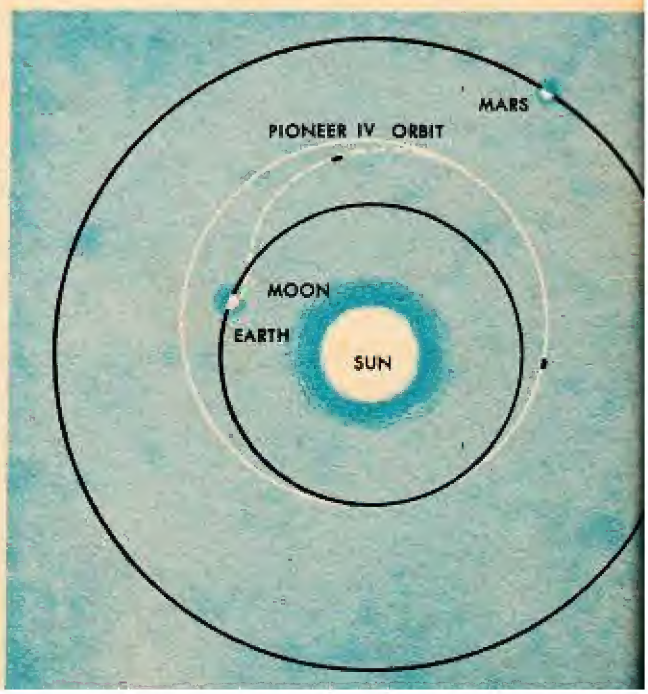
A spaceship taking off from another planet or the moon would also encounter gravity, or the pull of that heavenly body. In some cases, there is also an atmosphere. Thus, the escape velocity problem exists elsewhere in space as it does on earth.

On earth, once the speed of 18,000 miles per hour is reached, it is sufficient to offset the pull of the earth, or the gravitational force. At that speed, however, the rocket, spaceship or satellite would remain at approximately the same fixed distance away from earth, circling it as the moon does. We call this going into orbit. The first successful orbital shot was made in October, 1957, when the Soviet Union placed its first satellite *Sputnik I* in orbit around the earth. In January, 1958, the American satellite *Explorer I* was fired into its globe-circling orbit.

If the rocket fails to reach a speed of 18,000 miles an hour, it will not go into orbit, but will return to earth. The spaceship in which Russian cosmonaut Major Titov flew in August, 1961, reached orbital speed. The Mercury capsules in which American astronauts Commander Shepard and Captain Grissom flew travelled about 5,100 miles per hour. They did not go into orbit around the earth because the capsules had not reached orbital velocity.

To escape entirely from the earth's gravitational pull, it is necessary to attain a speed of about 25,000 miles per hour. At this speed, the rocket or spaceship would pull free of earth and head out into space. The United States' satellite *Pioneer IV* reached this high speed and left the earth's gravitational pull. Like the planets, it went into orbit around the sun.

A rocket that misses the moon is attracted by the sun and goes into a planet-like orbit around our sun.



The Techniques of Flight

Who designed the modern spaceship?

One of the earliest attempts at a practical rocketship was made by a German named Hermann Oberth. Because he wrote serious technical books about rockets and space travel during the days immediately after World War I, he was hired by a film company to be technical adviser for a space-travel film called "The Girl in the Moon."

Although the film was not supposed to be anything but a fantasy, the spaceship Oberth designed for the picture was built very carefully, so that it solved many of the problems a spaceman would encounter in outer space. His spaceship, built over forty years ago, is similar to those designed today.

Hermann Oberth is the man responsible for the rocket countdown that we use today—10 . . . . 5, 4, 3, 2, 1, fire! He suggested that this be used in the film because it created suspense. If you have ever watched a rocket countdown, you know how suspenseful that counting can be.

What is orbital flight?

We know that all the planets are constantly moving—rotating on their own axis and, at the same time, revolving about the sun. If you wanted to go from earth to another planet, you would not be able to travel in a straight line. For example, suppose you aimed a rocket at Mars or Venus. By the time the rocket reached the spot at which you aimed it, the planet would have moved along in its orbit, and the rocket would miss its target entirely.

A simple way to explain the complexity of orbital flight is to watch two boys play a special kind of ball game. Usually, if two boys wanted to play catch, they would stand several feet apart and throw the ball back and forth. This would be the same as shooting a rocket from earth to another planet—if the two planets were standing still.

However, suppose we put one boy on a merry-go-round. He is moving in a circle, in the same way that the earth is rotating on its axis. If the boy on the merry-go-round waited until he was directly opposite the other boy on the ground before he threw the ball, the ball would never reach the other boy. As the ball was thrown from the moving merry-go-round, it would not only fly away from the merry-go-round, but it would also loop in the direction the merry-go-round was turning.

Suppose we place the boy on a moving train instead of a merry-go-round. If he tried to throw the ball to the boy on the ground when his train was directly in front of the other boy, the ball would never reach its target. The ball would travel out away from the train, but it would also travel in the same direction as the train. It would travel in an arc. This train travel is similar to the earth's revolution in its orbit around the sun.

Actually, we would have to put the boy on a merry-go-round and then put the merry-go-round on a moving train if we wanted to duplicate the two motions of the earth—its rotation and its revolution in orbit.

It would take a lot of skill and practice

for the two boys to play catch this way. Of course, in our solar system, both planets are moving, and that would mean both boys would have to be on merry-go-rounds that are on moving trains. Imagine how difficult it would then be to play catch!

This is what is involved in orbital flight. Instead of firing a rocket in a straight line, we have to fire it in an arc and make adjustments and corrections for the rotations of both planets and the movements in their individual orbits.

At its nearest point, the earth and Venus are 26 million miles apart. If they were both perfectly still, we could fire a rocket or spaceship that would travel the 26 million miles and land on Venus. This, however, is a theoretical minimum distance.

The actual flight would be much longer, since in space we have the merry-go-round and train movements at very high speeds.

The Space-Age Guide to the Planets on page 48 shows the theoretical minimum flight times from the earth to the different planets. These are calculated on a straight-line flight if the planets were absolutely still and the spaceship were travelling at 25,000 miles an hour.

In reality, however, the flight would take much, much longer, since we would be travelling in an arc.

How can we navigate in a spaceship?

Orbital flight plans are made by special flight teams composed of astronomers, space technicians, mathematicians, astronauts and other specialists. Any flight to the moon or the planets depends upon the sun's gravitational pull. Despite the earth's rotational and elliptical motions and the orbital pattern of the moon or a planet, the basic flight pattern recognizes that the sun continues to exert its "pull" on all bodies in our solar system. In a flight to the moon, the moon's pull is used to take the spacecraft into lunar orbit.

Even if all the calculations are extremely accurate and the weather and space conditions are ideal, there is always the small possibility that the satellite or spaceship may go astray. The slightest veering off course, over such a long distance, can mean missing the landing target entirely.

Radio telescopes keep in constant communication with the satellite or ship as it speeds through space. The information received from the many tracking stations is gathered in a control centre. Here the information is interpreted with the assistance of a computer, so that fast, accurate answers are assured for all concerned.

To correct the course of a satellite or unmanned spaceship, radio signals are beamed at the ship in flight. These are picked up by the receiver and activate various controls. The direction finding equipment of a space-craft can also be 'locked' onto a star, for example, Canopus. The firing of compressed air through special vents or the setting off of short rocket blasts will correct faults in flight. This was the method used by the Russians in the flight of their cosmonaut

Major Gagarin. The space vehicle in which he travelled could be controlled only by the ground crew and not by the cosmonaut himself.

On the other hand, American spacecraft have been designed to allow the astronaut more control over his vehicle, so that he can make adjustments in flight if necessary. The landings on the moon could be controlled by the spacemen themselves. Of course, if necessary ground control could take over.

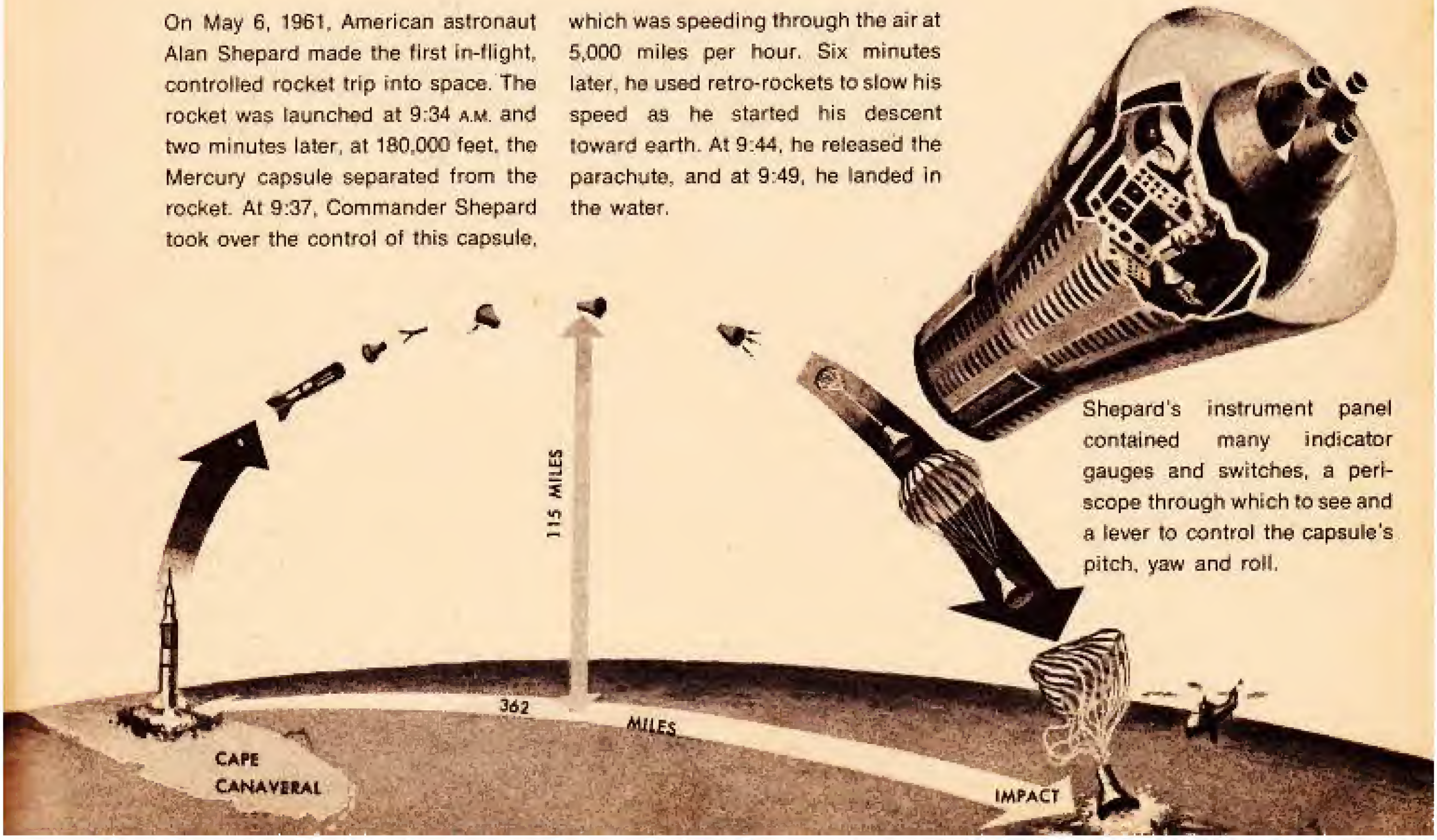
Only the slightest movement is necessary to alter the course of any rocket or spaceship. Instruments within the ship or on the ground receiving signals back from the ship, can tell if the vehicle is *yawing*; that is, if its nose is swinging from side to side.

Instruments can also tell if the vehicle is *pitching*; that is, if the nose if moving up or down. Once the air is fired through the special vents or a short rocket blast is used, the ship is back on course and on its way.

Why is re-entry a problem?

Returning to the earth from space is as great a problem as leaving the earth for space. For many years scientists have worked to overcome the difficulties of re-entry. As you remember, we saw that there was no air in space. We start to encounter air in our atmosphere. The gases in our atmosphere are made of many little atoms. The closer to the earth, the greater the number of atoms in the air. This is true because air has weight, and the miles and miles of air on the top press down on the

On May 6, 1961, American astronaut Alan Shepard made the first in-flight, controlled rocket trip into space. The rocket was launched at 9:34 A.M. and two minutes later, at 180,000 feet, the Mercury capsule separated from the rocket. At 9:37, Commander Shepard took over the control of this capsule, which was speeding through the air at 5,000 miles per hour. Six minutes later, he used retro-rockets to slow his speed as he started his descent toward earth. At 9:44, he released the parachute, and at 9:49, he landed in the water.



Shepard's instrument panel contained many indicator gauges and switches, a periscope through which to see and a lever to control the capsule's pitch, yaw and roll.

Taking a trip on a switchback, you can feel some of the sensations of a space flight. As the train comes rushing down, you are subjected to a positive "g" force. Your body feels as if it were being pushed through the seat, and the blood rushes out of your brain. At the top of a fast rise in the train, you are subjected to a negative "g" force. You feel as if you will continue going into the air, and extra blood is forced into your brain. When you go around a turn quickly, you are subjected to a transverse "g" force. Your body feels as if it will fly to one side; at this time, the blood in your body is being pushed in the same direction. You, like many pilots and spacemen, can stand this force better than the other "g's".

air below.

A spaceship travelling at thousands of miles an hour begins to come into the atmosphere. Here it comes into contact with the atoms in the air—it bumps into them, and the rubbing of the air atoms against the spaceship creates friction. Heat is created by this friction. As the rocket comes closer to earth, the number of atoms in the air increases. This results in greater friction, thus, greater heat.

If the spaceship did not have specially-treated surfaces, the outside metal skin of the ship would burn because it gets so hot. Even if the metal is treated so that it can withstand high temperatures and not burn, it becomes very hot inside the ship.

Therefore, it is necessary to insulate the spaceship so that the man inside can withstand the heat.

Human Factors in Space Travel

What are the dangers to man in space travel?

Building a spaceship for space exploration is only part of the problem which we face in space exploration. Preparing the men to travel in these ships is the other part. Every advance in the science of transportation presents a problem and a challenge to man. More than 150 years ago, when the first railroad trains were introduced, there were some people who believed that if man travelled at a speed of more than twenty-five miles per hour, he would die because his body could not stand the shock. While we have come far from this idea, we recognize that space travel does present certain obstacles to man.

For example, we know that as man goes into space he will be exposed to a greater amount of cosmic radiation. We also know that he will be exposed to an atmosphere in which there is no oxygen to breathe. He will be travelling in dark space that is very cold. These problems can be solved by proper construction of the spaceship. But what about the other difficulties man may encounter?

Can man work normally in space?

The first spacemen had to live and work in very cramped spacecraft. Early craft had just enough room for a man's body, and even in the Apollo capsule, which carried three men to the moon and back, there was only as much room as inside an estate car.

For short flights, the spacemen had to put up with cramped conditions; but men have now spent up to 84 days in space

A spacesuit (such as this one worn by Aldrin on the moon) enables a man to live in space by maintaining the correct environment, and by protecting him from some of the dangers in space.

—in Skylab, an orbiting space station and laboratory. Skylab was a large spacecraft with plenty of room in the living and working areas, and, to make conditions as normal as possible, the astronauts took books, games and taped music with them for relaxation. The men on Skylab found that they could live comfortably and work efficiently inside the spacecraft. In fact they managed to do more work than expected.

What is the *g* factor?

The normal pull of gravity on earth is a force that scientists call "one gravity" or 1 *g*. When a spaceship is taking off, it builds up speed to reach 18,000 miles an hour to go into orbit, or 25,000 miles an hour to escape from the earth. At this time there is an increase in the *g* factor, just as there is when you are standing in a lift and it starts to rise suddenly and rapidly. The earth is pulling on you just as it pulls on the spaceman, even though the lift or spaceship is using its power to rise rapidly.

As the *g* force increases, the weight of your body also increases—you feel much heavier. Thus, if you weigh 10 stone (normal weight under the normal 1 *g* force), you would weigh 20 stone under a 2 *g* force.

Very high *g* forces can cause you to "black out" or lose consciousness, since the blood cannot circulate properly through your body. Air Force pilots are often subjected to forces as high as 7 *g* during a high-speed power dive. However, if they wear space clothing, or stay in a special position, they can overcome the bad effects of this high *g* factor.

How does a space suit help a pilot?

The space suit provides an essential safety factor for the spaceman just as it does for

high-altitude pilots. It helps to control temperature and air pressure and assures its wearer of a supply of oxygen. The suit is made of a strong, lightweight material that fits the body like a glove. Like the glove on your hand, there is a minute space between the suit and the body in which there is air.

Pressure control is one of the more important reasons for using a space suit. As we go higher above the earth, the air pressure decreases. The normal human being has about four quarts of blood in his body. If you went up to 25,000 feet—about 4¾ miles—above the earth without a space suit or without a pressure cabin in a plane, the oxygen in your blood would bubble out as a gas. The normal four quarts of blood would need the same space as twelve quarts on the ground. At 50,000 feet, the oxygen

A controlled dive of a conventional plane puts this man in a weightless state. His reactions are carefully checked.

gas would expand further, making the space needed for the four quarts almost the same as sixty-eight quarts on the ground. You can readily see that your body would virtually explode as the blood expanded.

In addition, the space suit is connected to several tanks in the spaceship. One tank maintains the proper air pressure; another supplies the oxygen; still another takes the harmful carbon dioxide, which you exhale, out of the suit. Furthermore, the oxygen supplied in the suit is temperature-controlled so that no matter how cold it gets outside the spaceship—or inside—your body remains comfortable.

To help overcome the high *g* forces to which the spaceman is exposed during take-off, he has to use a special seat. This seat is something like a bed, so that his body appears to be lying down in the ship. In this position it is easier for his heart to pump the blood to all the parts of his body as compared with a standing or sitting position.

How does a spaceman train for the high *g* factors?

To prepare the space traveller for the high *g* factors he will experience in take-off and in landing, he is trained in a *centrifuge* (CEN-TRI-FUGE). This is a large machine with a rotating arm to which a model cabin of a spaceship is attached. The motor of the machine rotates the arm at faster and faster speeds, and the spaceman in the cabin is thus subjected to increased *g* pressure. Some of the astronauts have been subjected to a force as high as 40 *g*. If the man normally weighed 14 stone, his body would weigh 3½ tons or 7,840 pounds under this force. Many spacemen have been able to take this pressure for short intervals and still remain conscious.

How does "weightlessness" affect man?

As we leave the earth, the pull of earth's gravity gets less until we cannot feel it at all. Without gravity to hold it down, everything floats. This is called "weightlessness". It can be an uncomfortable feeling, similar to that felt when a lift starts or stops suddenly.

Doctors were interested in what would happen to men's bodies during long, weightless flights in space. This was answered by the Skylab astronauts. Because there is no gravity to pull their bodies down towards their feet, their spines stretched and they all grew one or two inches. Also their faces became fatter and their legs, chests and tummies thinner. This was due to the body fluids moving upwards. The astronauts did not continue growing all the time. After a

It takes about 3/10 of a second for the image that the eye sees to reach the brain and for the brain to tell the pilot what to do. If you were flying at the X-15's previous record speed of 3,690 miles per hour, your plane would travel 1,585 feet in that 3/10 of a second.

while the changes stopped and they remained in that condition until they returned to the earth. They regained their original size after a few days under the normal pull of gravity.

With all these peculiar effects on the astronauts' bodies, it is necessary to have constant medical checks. When a spaceman is wearing his spacesuit, his heartbeat and other body functions are checked automatically by ground control. The Skylab astronauts did not normally wear spacesuits, so they had to do medical tests every few days. They found that the body changes were less dramatic if they took regular exercise for at least an hour a day.

Because everything floats in space, the astronauts have to be careful to secure themselves and all their tools. When the men in Skylab wanted to work in one place, they anchored themselves to the floor using special shoes that fit into the special grid floor. If they weren't securely fixed, whenever they pressed a button they would drift backwards.

How important is "reaction time" in space travel?

Flying at high speeds in a spaceship creates many problems for the spaceman. One of these is the time he takes to react to signals from the ground or warnings from his instrument panel. In the many studies made by doctors and psychologists of people's reactions, it has been found that it takes about three-tenths of a second to react. For example, if you put your hand in some very hot water, it would take about three-tenths of a second before you pulled it out. That is the time it takes for the signal from nerves in your hand to reach your brain—for your brain to decide what to do—and for your brain to order your muscles to pull your hand away. This three-tenths of a second is called *normal reaction time.*

Before men went into space, doctors did not know if living in space would

In February, 1961, an astro-chimp named Ham became the first earthly creature to operate controls in a space capsule.

slow the spaceman's normal reaction time. If his reactions were too slow he would not be able to pilot his own craft, it would have to be controlled from the earth and this would limit the distance he could travel into space. There would be little point in sending a man into space if he is only to be a passenger unable to work.

Scientists have tested men under simulated spaceflight conditions on earth. They also sent a trained chimpanzee into space before sending a man. The tests showed that the reaction times of neither man nor chimpanzee were affected by spaceflight conditions.

This has been confirmed by all the spacemen on their many flights. They have been able to control their spacecraft and to carry out the difficult manoeuvre of docking two spacecraft. When things have gone wrong, as with Skylab, men have been able to carry out repairs. Skylab was damaged on launch and if men had been unable to work in space, it would have been a complete failure. Instead the first three astronauts to visit Skylab managed to repair it, and it completed its planned mission.

The Skylab astronauts showed that although their bodies took time to adjust, they were able to work well in space. One problem that did affect them, especially at the beginning of a mission, was motion sickness—the space equivalent of sea sickness. This has affected about half of America's astronauts.

Into Space by Stages

How have we progressed in space?

When embarking on the hazardous task of sending a man to the moon we had to take all possible precautions. First probes were sent to find out as much as possible about the environment in which the spaceman would find himself. Progress was slow as everything had to be tested before the next step could be taken. Men were put into orbit around the earth, first singly then in pairs. They learnt to "walk" in space and practised in the vehicles that would take them to the moon. Finally, when all possible tests had been done, men went to land on the moon.

However, the moon has only been part of our aim in going into space. Both America and Russia have launched orbiting laboratories. The American Skylab

The American orbiting laboratory, 'Skylab', had to be patched up by its crew before they could live and work in it. After several repairs, the third and last crew stayed in it for 84 days.

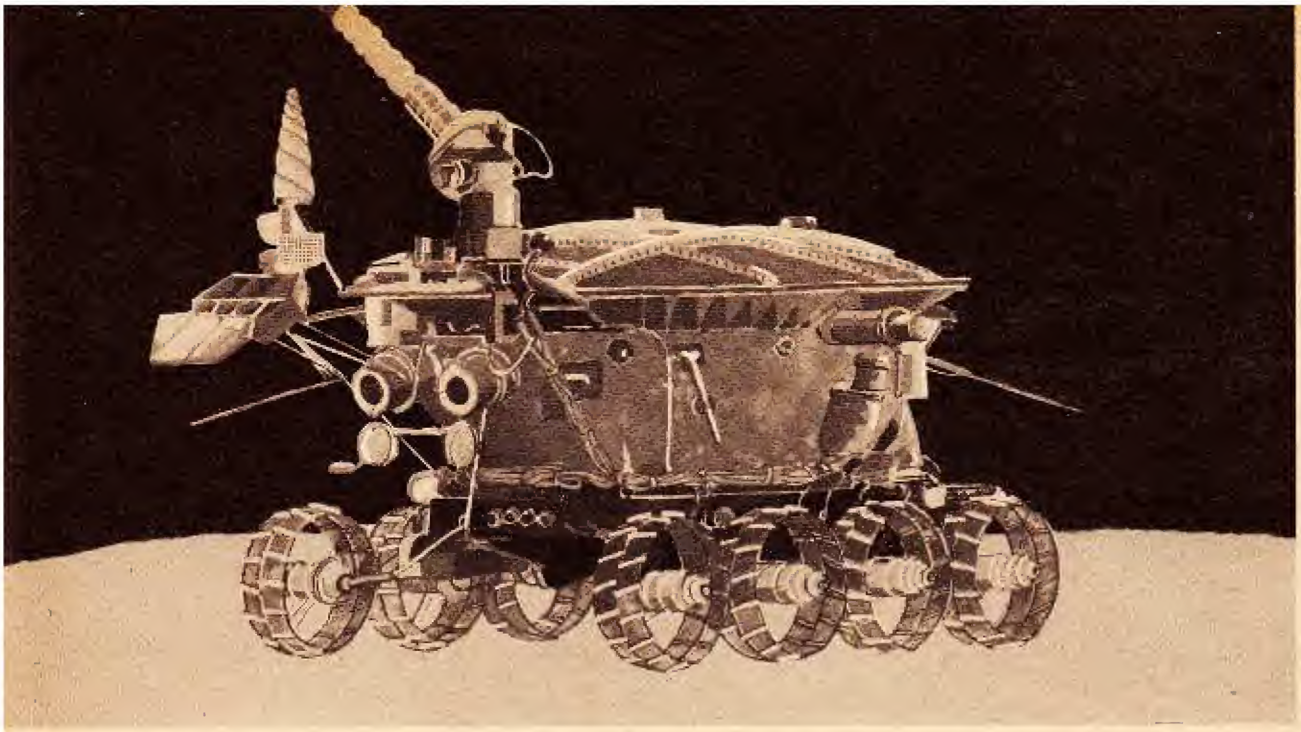
was used by three groups of astronauts who carried out experiments. It carried telescopes to look at the sun from outside our atmosphere, and it looked in towards the earth from space.

A great deal has been achieved by unmanned spacecraft. We use satellites every day to relay television and telephone conversations, and weather satellites help weather forecasters. One of the new space vehicles being developed is called the Space Shuttle. It is built like an aircraft with re-usable rocket boosters for take-off. The Shuttle will carry scientists into orbit where they will be able to do experiments and repair or collect satellites needing attention. It will also be able to launch new satellites. At the end of each mission it will return to earth, landing like an aeroplane, and can be used again.

Why were unmanned space probes sent to the moon?

Before man could safely land on the moon, much more had to be known about it than could be learnt from the earth. We did not know if the surface would support a manned landing or where the best landing sites were. To answer these questions was one of the tasks of the unmanned spacecraft sent to the moon by both Russia and America. These unmanned "lunar probes" were the trail blazers for the spectacular manned Apollo moon flights.

In 1959 Russia's Luna 3 spacecraft flew around the moon and photographed its rear face. This was man's first glimpse of this side of the moon which always faces away from earth. During the 1960's America used three types of craft in her unmanned exploration of our nearest neighbour in space—Ranger, Orbiter and Surveyor. Ranger was fired at the moon and took close-up pictures before crashing into it. Orbiter photographed possible Apollo landing sites



This robot explorer, 'Lunokhod', roamed over the moon's surface sending information back to earth.

from lunar orbit. Surveyor soft landed on the moon and carried out experiments on the surface. The last of these was launched in 1968. Since then America has only sent manned Apollo spacecraft to the moon.

Russia continued her Luna programme achieving remarkable successes with her unmanned lunar explorers. In September 1970, Luna 16 landed on the moon, collected a sample of lunar soil and, still under remote control from Russia, took off and returned the samples safely to earth. The amount of material collected was much smaller than that brought back by the Apollo 11 astronauts just over a year earlier; but the risk involved was also much smaller. Two months later, in November 1970, Luna 17 unloaded its cargo, an eight-wheeled, remotely controlled moon rover called Lunokhod, onto the surface of the moon. Lunokhod roamed around the moon, under control from earth, for nearly a year, working and taking measurements during the lunar day and hibernating during the lunar night.

How did manned spaceflight begin?

The world's first spaceman was Russia's Yuri Gagarin, who made one orbit of the earth in his Vostok spaceship in April 1961. He flew over 25,000 miles in 108 minutes at an average height of 150 miles. This started a series of one-manned flights by Russian cosmonauts and American astronauts in their Vostok and Mercury spacecraft. Among them was a woman, Valentina Tereshkova, who flew in Vostok 6.

The next step was the launching of bigger and more complex spacecraft capable of carrying more than one man. Many of the techniques that would be used during the manned moon flights were practised with these spacecraft. The first multi-manned spacecraft was Russia's Voskhod 1, launched in October 1964 with three men on board. America's two-man craft was called Gemini. By the end of the ten manned Gemini flights in 1966, man had lived and carried out complicated tasks in space for periods of up to two weeks, he had

"walked" in space and had successfully docked two spacecraft. The next step in America's programme was Apollo, whose aim was to land a man on the moon.

How is a manned moonflight made?

There are several ways to send a man to the moon, but the only one used so far is the one employed in the Apollo programme. There are no known plans for any more trips to the moon by man in the immediate future.

The Apollo spacecraft, carrying three astronauts, is launched by a Saturn V rocket, the most powerful rocket ever built, and placed into a so-called "parking orbit" about 100 miles above the earth. At exactly the right moment, the third stage engine of the rocket is re-fired to place Apollo on a path to the moon at about 25,000 mph. The Apollo spacecraft consists of three sections. The Command Module (CM) acts as the astronauts' home on their journey to and from the moon. The Service Module (SM) carries equipment to supply the CM with electrical power, etc. The Lunar Excursion Module (LEM) is a spider-like vehicle in which two astronauts descend to the surface of the moon.

As soon as Apollo has left earth orbit, the combined CM and SM (CSM) separates from the rocket's third stage, turns around and docks with the LEM. The whole spacecraft then pulls clear and leaves the rocket behind. On reaching the moon, Apollo goes into orbit around it. The two astronauts who will land on the moon transfer from the CM to the LEM. This then separates from the CSM, which remains in lunar orbit with a solitary astronaut on board, and descends to the moon's surface. The landing is controlled by small rocket engines on the LEM.

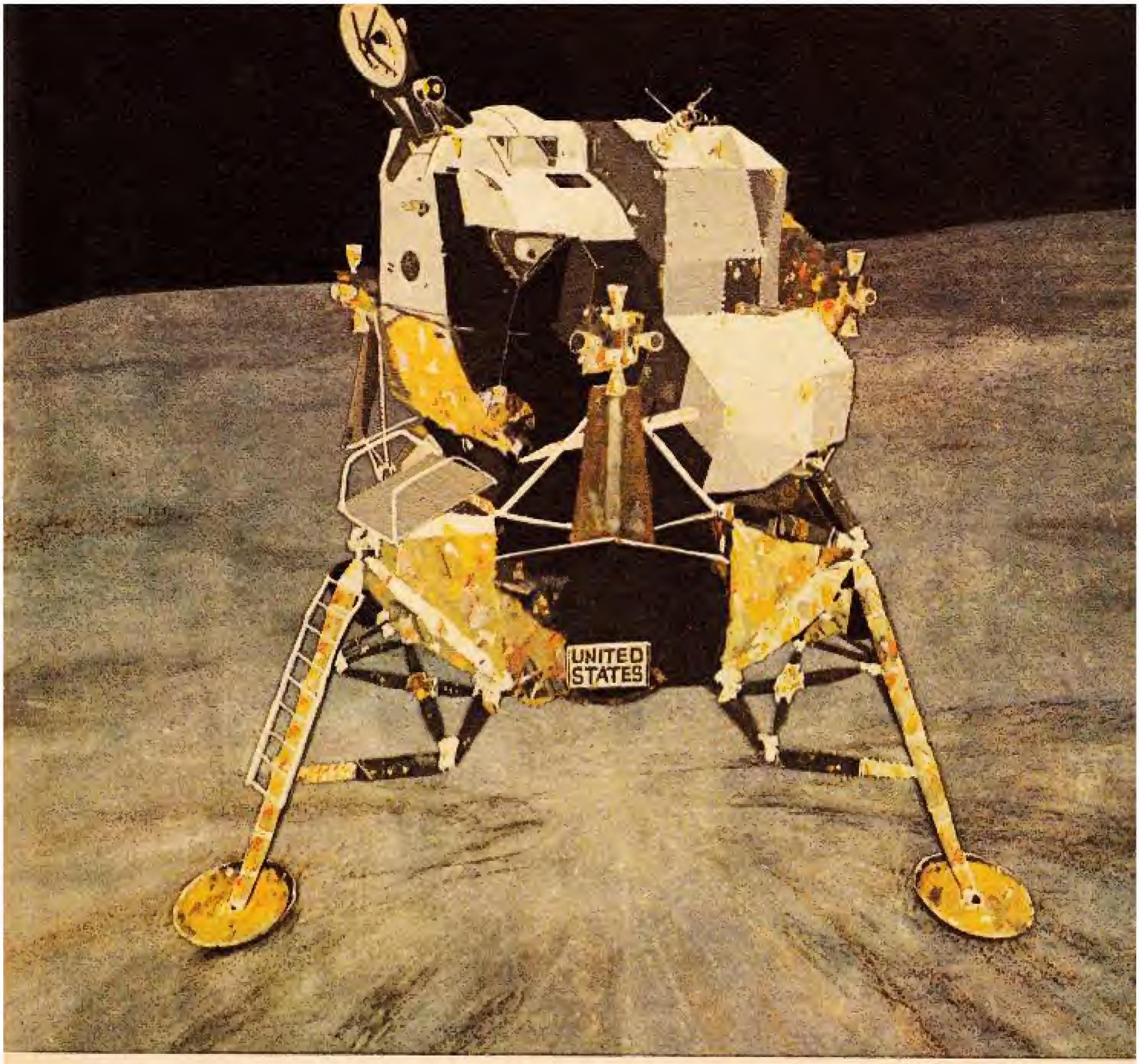
When the stay on the moon is over, the ascent stage of the LEM, using the base of the LEM as a launching platform, rises to dock with the awaiting CSM. The crew transfer to the CM, the LEM is jettisoned and, at the right moment, the engine on the CSM is fired to send the spacecraft on a course back to earth. Just before the upper limit of the earth's atmosphere is reached, the SM is detached and the CM re-enters the atmosphere, heatshield first. This shield is designed to withstand the very high temperatures developed during re-entry. When the CM is safely through this dangerous phase of the mission, parachutes are used and the capsule descends gently to the sea to be picked up by waiting rescue ships.

There was not the thick layer of dust on the moon's surface that some astronauts had predicted. There were a great many rocks, many of volcanic type, some very large, and there was a lot of dust-like material of which about 50% appeared to be made up of glass-like substance, much of it in the form of little glass spheres or marbles. The moon is a completely silent world due to the lack of atmosphere.

These moon missions proved that man could live on the moon provided he took his environment with him. His spacesuit provided the correct temperature and pressure and air to breathe, and his spacecraft carried the necessary food and water. It is very costly to bring all this from earth, so in the near future man will be limited to short visits to the moon, although none are planned at present.

What is Apollo-Soyuz?

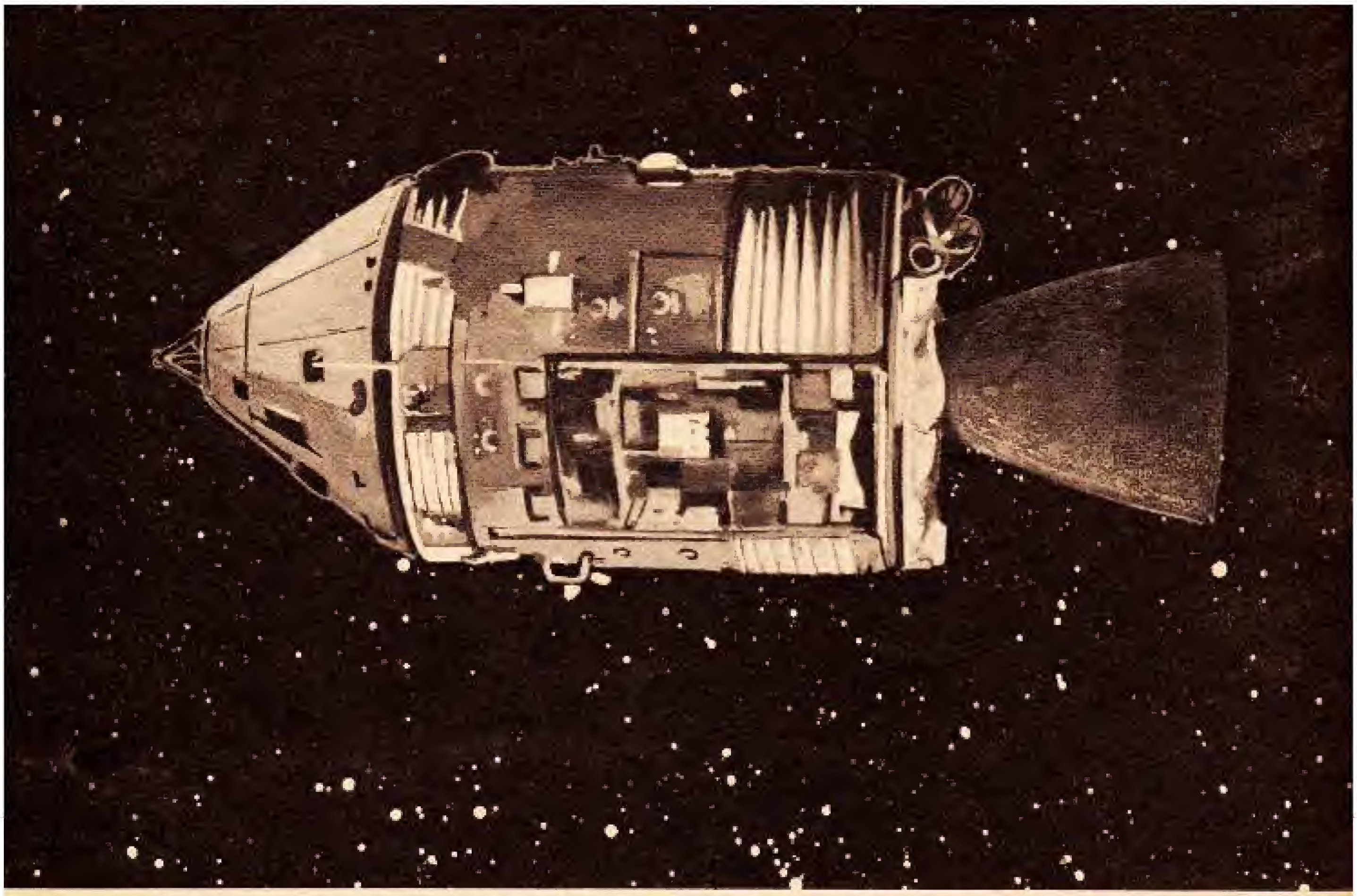
The first international manned space mission took place in July 1975. A Soyuz spacecraft, carrying two cosmonauts, was launched from Russia and



The Lunar Excursion Module can land two men on the moon and at the end of the mission carry them up to rejoin the Command and Service Module in orbit. The astronauts can live for several days in the Lunar Module.

they were joined in orbit some hours later by three American astronauts in an Apollo spacecraft. The two spacecraft docked using a special docking mechanism that had been developed for this mission. The spacemen visited each other's spacecraft, shared meals and carried out several joint experiments.

After two days the spacecraft parted, and the individual craft remained in orbit carrying out their own experiments for a few more days. This Apollo-Soyuz mission proved that international co-operation is possible. It also increased the possibility of a space rescue if an accident should occur. With the new universal docking device it would be possible for spacemen of either nation to come to the aid of astronauts or cosmonauts stranded in space.



The Command and Service Module carried three men to the moon and back. It stayed in lunar orbit with one astronaut inside, whilst the other two landed on the surface in the Lunar Excursion Module.

What did the Apollo astronauts do on the moon?

On 20th July 1969 Neil Armstrong, the first man to set foot on another body in space, took his momentous step off the bottom of the ladder of Apollo 11's LEM onto the lunar surface. On this first manned visit to the moon, the two astronauts spent less than a day on the moon, and each astronaut walked and worked actually on the moon's surface for about 2 hours. They remained within easy reach of the LEM and collected about 50 pounds of lunar rock to bring back to earth. After some initial difficulty, the astronauts found it easy to move around the moon using the well known "kangaroo lope" motion. After setting up experiments that would continue working long after they had returned to earth, the two Apollo 11 astronauts returned to the LEM for a period of rest before they began their journey home.

Scientists had feared that the first men on the moon might bring back moon germs, so on their return the astronauts spent 17 days in quarantine. These fears proved groundless and this was not repeated for all the other Apollo missions.

Altogether, six Apollo spacecraft landed on the moon, each one staying longer than the previous one. They landed at different sites along the moon's equator and collected rocks from each place they visited. The last three moon missions carried a lunar rover vehicle so that the astronauts could go further from their LEM. They travelled as far away

from base as 6 miles at a speed of up to 8 mph over the uneven rocky surface and collected rock samples wherever they went. Altogether about 840 pounds of moon rock was brought back to earth, and this will keep geologists busy for many years.

They also carried out experiments on the moon and set up experimental packages (ASLEPs) on the surface, which would carry on working when they had left. These were designed to increase our knowledge of the moon's structure and the space around the moon. One of these left by Apollo 11 was a laser reflector which bounces laser signals, sent by scientists on earth, back to them, and helps them to measure the exact distance to the moon. Others recorded "moonquakes".

The moon is made of rocky material similar to but not exactly like the earth. Much of the material is similar to the earth rocks, but the presence in large amounts of fairly rare elements makes it unlikely that the moon once formed part of the earth. It is likely that the earth and moon were both formed at the same time, possibly from the same cloud of gaseous material, or from matter ejected by the sun.

Other Worlds

Will man reach other worlds similar to ours?

From what we know of our solar system, it appears unlikely that we will find intelligent life as we know it on any of the other planets. Some micro-organisms and plants might exist, but beings shaped like man or the fabled Martian monsters are not likely. Human life, according to scientists, developed on this planet because of the unique combination of many factors—the earth's distance from the sun, the composition of our atmosphere, the structure of the earth's surface, the presence of certain organisms on the face of the planet. Yet, many ask, are we the only ones in the universe?

Although astronomers have never actually seen a planet outside of our solar system, they now recognize that other solar systems exist. With powerful radio telescopes, they have located these distant systems. Astronomer Harlow Shapley has estimated that there may be life in the planetary systems of one out of a million stars.

Let's take this million-to-one chance that astronomer Shapley believes and see what the chances really are! Our best scientific information tells us that there are over 100,000 million stars in our own galaxy, and that there are about 100 million galaxies in the universe. This means that there are some 10 trillion (10,000,000,000,000,000,000) stars in the universe.

Suppose that only one out of a million of these stars is a sun like our own sun. That would mean that there are some 10 billion possible other suns in the universe. Again, let us use Shapley's one-out-of-a-million chance to find how

many of these suns could possibly have a planet like earth—a planet 93 million miles away, a planet with oxygen in the air for breathing, a planet on which man could live as he does on earth. There would be about 10 million other planets in the universe that could physically resemble earth.

Finally, suppose we use the one-in-a-million chance to find out how many of these have human life just as we have on earth. We would then find that there are ten other "earths" with human life somewhere in this vast universe.

Naturally, it would be quite a task to find these ten out of the millions upon millions of stars and planets in the universe. But if we did, what would man be like? Would he still be in the cave-man stage? Or would he have developed a society far beyond ours? What would happen if we did meet a man from outer space?

It is these unknowns and man's unending thirst for knowledge that takes us into space in search of other possible worlds like ours.

Space-Age Guide to the Planets

Planet	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
Distance from the Sun (millions of miles)	36.0	67.2	92.9	141.5	483.9	886.0	1783.0	2791.7	3670.0
Theoretical Minimum Time to Reach Planet from Earth	83 days	45 days		58 days	1 year, 8 months	3 years, 5 months	7 years, 5 months	12 years, 2 months	12 years, 2 months
Diameter (miles)	3,000	7,700	7,927	4,200	89,000	75,400	32,000	30,800	3,700
Time to Complete One Orbital Revolution Around the Sun (measured in Earth time)	88 days	224.7 days	365.26 days	687 days	11 years, 314 days	29 years, 168 days	84 years, 7 days	164 years, 285 days	248 years 146 days
Time for One Rotation on its Axis (measured in Earth time)	59 days	243 days	23 hours, 56 mins	24 hours, 37 mins	9 hours 50 mins	10 hours, 14 mins	10 hours, 49 mins	15 hours, 40 mins	16 hours, 6 days 9 hours
Surface Gravity (measured in terms of 1 g on Earth)	0.35	0.88	1.00	0.38	2.64	1.17	1.17	1.18	?
Weight of a Man on the Planet if He Weighed 14 st. 4 lb. on Earth	5 st.	12 st. 8 lb.	14 st. 4 lb.	5 st. 6 lb.	37 st. 10 lb.	16 st. 10 lb.	16 st. 10 lb.	16 st. 12 lb.	?
Escape Velocity (miles per hour)	9,700	23,000	25,000	11,500	133,200	79,200	49,320	57,600	22,000
Average Temperature on Surface	−210°C. to 510°C.	480°C.	22°C.	−23°C.	−150°C.	−180°C.	−210°C.	−220°C.	−230°C.
Number of Moons	0	0	1	2	13	10	5	2	0

HOW AND WHY

These books answer the questions most often asked about science, nature and history. They are presented in a clear, readable style, and contain many colourful and instructive illustrations. Readers will want to explore each of these fascinating subjects and collect these volumes as an authentic, ready-reference, basic library.

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